

details shown on the plans. These units shall be reinforced with steel reinforcement when shown on the plans. Steel reinforcement shall be in accordance with 910.01.

When required for driveways, crossings, closures, or for other reasons a depressed or modified section of curb is indicated, curbing with the required modification shall be furnished.

913.06 Precast Concrete Units Not Otherwise Covered. These units shall be cast in substantial permanent steel forms. Structural concrete used shall attain a minimum 28 day compressive strength of 20.7 MPa (3,000 psi) as determined in accordance with AASHTO T 22. When air entrained concrete is specified, it shall have an air content of from 5 to 8 percent by volume. The precast units shall be cured in accordance with AASHTO M 170. Water absorption of individual cores taken from such units shall not exceed 9 percent. Additional reinforcement shall be provided as needed to handle the precast units.

913.07 Flexible Delineator Posts. Flexible delineator posts shall be made of flexible plastic material. The post shall be straight and have a smooth surface free from cracks, flaws, seams, laps, blisters, and edges affecting the strength, durability, or appearance. The cross section of the post may be round, oval, or T shaped and the width shall not exceed 150 mm (6 in.). They shall be white, yellow, or orange in color as determined by the location in which they are used.

The reflective device on these posts shall be reflective sheeting matching the color of the posts, in accordance with 912.10(d)4, and shall have minimum dimensions of 75 mm (3 in.) by 200 mm (8 in.). The reflective device shall be applied directly to the post and protected in a manner that minimizes the damage upon impact.

When installed the flexible post shall withstand, without damage, repeated impacts from a motor vehicle's front bumper at speeds up to 80 km/hr (50 mph) at ambient air temperatures from - 7p C (20p F) to 49p C (+120p F). It shall be able to bend to an angle of 85 degrees from vertical and right itself to within 10 degrees of the vertical immediately and stand erect within 4 hours within the same ambient air temperature range.

Manufacturers of flexible delineator posts shall prequalify for supply by providing the Operations Support Division with posts for field evaluation to determine acceptability. The Department will maintain a list of approved flexible delineator posts.

913.08 Delineators.

(a) Acrylic Plastic Delineators. These units shall consist of a hermetically sealed optical system with a circular plastic face and prismatic molded rear surface. The optical system shall have a minimum diameter of 75 mm (3 in.) with a minimum area of approximately 4520 mm² (7 in.²). The trademark of the manufacturer shall be molded legibly into the face of the lens. Color shall be clear (crystal or silver) or yellow in

daylight as well as when viewed by reflected light at night. Photometric or optical requirements shall equal or exceed the following minimum values:

Observation Angle Degrees	Entrance Angle Degrees	Specific Intensity lux (footcandles)	
		Clear	Yellow
0.1	0	1281 (119)	850 (79)
0.1	20	506 (47)	301 (28)

The opaque backing shall be made from aluminum sheet having a minimum thickness of 0.50 mm (0.02 in.). The backing shall form an integral part of the delineator and shall retain the optical system securely. Mounting shall be provided by a single aluminum grommited hole incorporated as part of the backing and shall be in the center of the reflector. The inside diameter of the grommet hole shall be 5 mm (3/16 in.).

For qualification or approval of the manufacturer, 100 delineators of each color which the manufacturer proposes to supply shall be submitted for tests. The delineators shall pass the test to determine adequate seal in accordance with 913.10(e)2. After qualification or approval of the manufacturer, a type C certification in accordance with 916 will be required.

(b) Reflective Sheeting Delineators. Single units shall consist of reflective sheeting affixed to an aluminum backplate. The unit shall be 75 mm by 200 mm (3 in. by 8 in.) in size, with a tolerance of ± 3 mm ($\pm 1/8$ in.) for the white (silver) delineator. Each multiple unit, amber or interstate yellow, shall consist of reflective sheeting affixed to an aluminum backplate 125 mm by 125 mm (5 in. by 5 in.) square with a tolerance of ± 3 mm ($\pm 1/8$ in.). The square unit shall be mounted as a diamond with one mounted at the top of the post and the other placed in a vertical row immediately below. The backplate shall be fabricated from sheet aluminum alloy 6061-T6 or 5154-H38, ASTM B 209M (ASTM B 209), with a minimum thickness of 1.626 mm (0.064 in.). Reflective sheeting shall be in accordance with 913.10(d)3.

Two mounting holes, 5 mm (3/16 in.) in diameter, shall be provided, one at the top and one at the bottom. The holes shall be 150 mm (6 in.) ± 2 mm (1/16 in.) center to center. Holes shall be in the corners of the square units so as to mount as a diamond. The face of the unit shall be coated after the fabrication.

Material furnished under this specification shall be covered by a type C certification in accordance with 916.

(c) Barrier Delineators. The delineators shall consist of a transparent acrylic plastic face, herein referred to as the lens, and an opaque back fused to the lens under heat and pressure around the entire perimeter to form a unit permanently sealed against dust, water, and water vapor. The reflector lens shall be colorless.

The lens shall consist of a smooth front surface free from projection or indentations other than for purposes of identification or orientation of the reflector. The rear surface shall have a prismatic configuration such that it will effect total internal reflection of light. The manufacturer's trademark shall be molded legibly into the face of the lens.

The reflector lens, having a minimum effective reflex area of 4194 mm² (6.5 in²), shall be methyl methacrylate in accordance with Federal Specification LP-380C, type 1, Class 3. Photometric or optical requirements shall equal or exceed the following minimum values:

Observation Angle Degrees	Entrance Angle Degrees	Specific Intensity lux (footcandles)	
		Clear	Yellow
0.1	0	1281 (119)	850 (79)
0.1	20	506 (47)	301 (28)

The entrance angle is the angle at the reflector between the direction of light incident on it and the direction of reflector axis. The observation angle is the angle at reflector between the observer's line of sight and direction of light incident on reflector. The specific intensity is the candlepower returned at the chosen observation angle by a reflector or reflective surface for each lux (footcandle) of illumination at the reflector.

Barrier delineators shall be initially approved for use with a type A certification and, if accepted, the product will be added to the Department's List of Approved Barrier Delineators. Following initial approval, material furnished under this specification shall be covered by a type C certification in accordance with 916.

913.09 Glass Beads. Glass beads shall be small spheroids manufactured from virgin or reclaimed glass. They shall be in accordance with the gradation set out below and, by reflection and refraction, improve the night visibility of traffic markings when they are applied in a suitable manner to the paint at the time it is applied. They shall be transparent and, in general, free from foreign matter. They shall not contain more than 25 percent defects which would cause the beads to be non-spherical or which would impair reflective properties as determined by testing according to ASTM D 1155 augmented by microscopic examination. Such defects include, but are not restricted to, milkiness, scratches, pits, air bubbles, fused beads, irregularities, and angularity.

The beads shall show an index of refraction of 1.50 or higher when tested in accordance with ITM No. 601, the liquid immersion method. They shall be in accordance with the following gradation when tested in accordance with ASTM D 1214, except sampling shall be as set out in the Manual for Frequency of Sampling and Testing, and a probe sampling device may be used to obtain a sample from the bag of beads.

170

Passing Sieve No.	Retained On Sieve No.	Percent	
		Minimum	Maximum
20 (850 μm)	30 (600 μm)	0	20
30 (600 μm)	50 (300 μm)	40	80
50 (300 μm)	80 (180 μm)	10	40
80 (180 μm)	—	0	5

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A minimum of 0.9 kg (2 lb) of glass beads shall be placed in a clean, washed, cotton bag furnished by the supplier and shall be subject to a moisture test. The bag containing the sample shall be immersed in a container of water for 30 seconds or until the water covers the beads whichever is longer. The bag shall be removed and any excess water shall be forced from the sample by squeezing the bag. The bag shall be suspended and allowed to drain for 2 hours at 21 \pm 22 \pm C (70 \pm 72 \pm F). At the end of this time, the sample shall be mixed in the bag by shaking the bag. The sample shall be slowly transferred to a clean, dry, standard glass funnel (Corning 6120). The entire sample shall flow through the funnel freely without stoppage. If the beads clog when first introduced into the funnel, it is permissible to tap the funnel lightly to initiate the flow.

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From each shipment or batch at each point of delivery, a random sample of three 23 kg (50 lb) will be taken for testing and approval of the shipment or batch. The 3 bag sample will be taken so as to represent rack or pallet subdivisions comprising the shipment. Not more than one bag shall be selected from an individual rack or pallet. The entire shipment will be accepted or rejected on the basis of each bag in this sample meeting all requirements set out herein. Evidence of caking, foreign matter, or lumping on any sample selected at random and inspected at the point of delivery will be sufficient cause for rejection of the shipment. No shipment shall contain more than 2 batches of glass beads. A batch is defined for this purpose as the continuous production of glass beads for one day.

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Beads shall be packaged in 23 kg (50 lb) standard waterproof bags. These bags shall be multi-walled, suitably stitched, and of sufficient strength to withstand shipping and handling without breaking. The bags shall be fabricated in a manner to provide easy opening. Each bag shall bear a label on which is shown the name and address of the manufacturer, net weight of contents, date of manufacture, batch or lot number, and rack or pallet number.

913.10 Traffic Signs. Traffic signs shall be designed to conform with applicable requirements of AASHTO Specifications for Highway Signs, Luminaries, and Traffic Signals, and the MUTCD. If there is a conflict for Interstate signs, the AASHTO requirements shall prevail.

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Overlap or butt splicing of reflective sheeting by the sign fabricator is not permitted on panel signs. Splices as supplied on the roll of sheeting by the sheeting

manufacturer, hereafter referred to as roll splices, are permitted subject to the following: a maximum of one roll splice per panel and a maximum of 3 roll splices per sign is permitted on a panel sign. Exit panels are considered as part of the signs they are attached to when fabricated under the same contract. If the exit panels are to be made for separate installation, only one roll splice is permitted on the entire sign.

220 Overlap splices on sheet signs shall be permitted only because of insufficient sheeting width on signs whose smaller dimension exceeds 1220 mm (48 in.) The overlap splice shall be installed in a shingle-type manner using a horizontal lap. The lap width shall be a minimum of 6 mm (1/4 in.). Butt slices are not permitted by the fabricator. Roll splices are permitted on sheet signs but shall not exceed one splice per sign.

230 All signs shall be packed for shipment and handled during construction in accordance with 802.01. Any sign or sign face damaged prior to acceptance shall be replaced or repaired. If replacement is required the sheet signs shall be replaced in entirety and the panel signs shall have the affected panels replaced. Repairs to the reflective sheeting shall be in accordance with the manufacturers' recommendations.

240 Repaired areas on panel signs shall not be larger than 75 mm by 75 mm (3 in. by 3 in.). Repaired areas of 25 mm by 25 mm (1 in. by 1 in.) or less shall be limited to a maximum of 3 per panel and a maximum of 6 per panel sign. Repaired areas of larger than 25 mm by 25 mm (1 in. by 1 in.) but no more than 75 by 75 mm (3 in. by 3 in.) shall be limited to one per panel and a maximum of 3 per panel sign. Repaired areas on a panel or on a panel sign shall be limited to the maximum number of small repaired areas and the maximum number of larger repaired areas or any combination thereof. No more than 20 percent of the total number of panel signs may be patched. Signs in excess of 20 percent shall have damaged panels replaced. Panels with sheeting cracked at the bend around the panel edge shall be replaced.

240 Repaired areas on sheet signs shall be less than 25 mm by 25 mm (1 in. by 1 in.) and shall be limited to one per sign. No more than 10 percent of the sheet signs may be patched. All damaged sheet signs in excess of 10 percent shall be replaced.

A sign with the metal face damaged greater than superficial deformation shall be replaced.

250 **(a) Sheet Signs.** The backing material for sheet signs may be made from sheet aluminum in accordance with ASTM B 209M (ASTM B 209), alloy 5052H38, alloy 6061-T6; sheet steel in accordance with ASTM A 653M (ASTM A 653), grade A, stretcher leveled with an extra smooth commercial coating of the galvanized-bonderized process, and a minimum Rockwell hardness of 65; or fiberglass reinforced plastic in accordance with 913.10(g).

Temporary signs may be of aluminum, steel, or plywood, unless otherwise provided.

260 Fabrication, including cutting and punching of holes but excluding holes for demountable copy, shall be completed prior to surface treatment. Material shall be cut to size and shape and shall be free from buckles, warp, dents, cockles, burrs, and defects resulting from fabrication. The surface shall be essentially a plane surface.

270 Metal signs base material shall be given a preliminary cleaning with an alkaline cleanser or grease solvent. Aluminum shall be rinsed, etched, rinsed again, and dried. If zinc oxide is present on steel material, it shall be removed with phosphoric acid or an inhibited pickling solution and rinsed with running water followed by a hot water tank rinse if necessary. All dirt and loose phosphate coating shall be removed from steel material with a tac rag. The back, edges, and all areas of steel material not covered with reflective sheeting shall be primed with a high quality, non-chalking, short to medium, oil primer and then with a high quality, short to medium, oil enamel. Painted steel signs shall be finished, in the color specified, with baking enamel meeting Federal Specification TT-P-489B in accordance with recommendations of the paint manufacturer.

Surfaces of sign backing material to which reflective sheeting is to be applied shall be treated in accordance with recommendations of the reflective sheeting manufacturer.

280 The bolts used to attach the sheet signs to steel, flanged, channel posts shall be 8 mm by 75 mm (5/16 in. by 3 in.) hex head cap screw type, full thread USS 18 threads per 25 mm (in.), complete with hex nut. The flat steel washers shall be 8 mm (5/16 in.) inside diameter by 14 mm (9/16 in.) outside diameter, thickness 2 mm (1/16 in.). Bolts, nuts, flat washers, and lock washers shall be stainless steel or be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153, class C. flat plastic washers shall be 8 mm (5/16 in.) inside diameter by 22 mm (7/8 in.) outside diameter 0.81 mm (0.032 in.) thickness.

290 Materials for stainless steel bolts, nuts, flat washers, and lock washers shall be in accordance with ASTM A 276, type 304. Materials for galvanized bolts, nuts, flat washers, and lock washers shall be in accordance with ASTM A 307, grade A.

The number of posts for mounting and the minimum thickness or gage of the sheet shall be as shown for the appropriate sign width.

Width mm (in.)	Number of Posts	Thickness mm (in.) Aluminum Sheet	Gage Steel Sheet
Up to 610 (24)	1	2.0 (0.080)	18 (1.22 mm)
635 to 760 (25 to 30)	1	2.0 (0.080)	18 (1.22 mm)
790 to 1525 (31 to 60)	2	2.50 (0.100)	16 (1.5 mm)
1550 and over (61 and over)	2	3.20 (0.125)	15 (1.9 mm)

(b) Panel Signs. Aluminum extruded panels shall be in accordance with ASTM B 221M (ASTM B 221), alloy 6063-T6, and be 230 or 305 mm (9 in. or 12 in.) in width. Extruded aluminum panels shall be flat and straight within tolerances established by the aluminum industry. Typical weights per meter (linear foot) for panels shall be: 230 mm (9 in.), 0.28 kg (2.00 lb); or 305 mm (12 in.), 0.34 kg (2.48 lb). Aluminum post clips shall be in accordance with ASTM B 26M (ASTM B 26) or B 108, alloy 356.0-T6, and be placed in accordance with the following sign width classifications:

1. Up to and including 7.30 m (24 ft), clips shall be placed on both sides of each post at the top and bottom of the sign. Intermediate clips shall be placed one on each panel on each post and shall alternate left to right on each post.
2. Over 7.30 m (24 ft), double clips shall be used, one on the right side and one on the left side on each post per panel width, plus the sets necessary to attach the top and bottom of the sign.

Aluminum post clip bolts shall be 10 mm by 44 mm (3/8 in. by 1 3/4 in.) by 44 mm (1 3/4 in.) 16 NC threaded, ASTM B 211M (ASTM B 211), alloy 2024-T4, with 10 mm (3/8 in.) 16 NC threaded lock nuts, ASTM B 211M (ASTM B 211), alloy 2017-T4. Lock nuts shall be torqued 2 full turns beyond snug fit. Washers shall be flat, ASTM B 209M (ASTM B 209), alloy Alclad 2024-T4. Panel bolts shall be 10 mm by 19 mm (3/8 in. by 3/4 in.) 16NC threaded, ASTM B 211M (ASTM B 211), alloy 2024-T4, with 10 mm (3/8 in.) 16 NC threaded standard hex nuts, ASTM B 211M (ASTM B 211), alloy 6061-T6.

Formed steel panels shall be in accordance with 912.10(a) for sheet steel, shall be 150 to 305 mm (6 in. to 12 in.) in width, and shall be 1.5 mm (16 gage) and have a flatness of 0.24 mm per m (1/32 in. per ft) of length and 0.1 mm per mm (0.004 in. per in.) of width. Post clips shall be of 5 mm (3/16 in.) steel plate or bar of structural quality in accordance with ASTM A 36M (ASTM A 36). They shall be hot dip galvanized after fabrication in accordance with ASTM A 153. The clips shall be 50 mm (2 in.) wide by 75 mm (3 in.) long. They shall be formed in an arc along the long dimension, with a rise between the arc and the chord of 8 mm (5/16 in.). There shall be a slot 10 mm by 19

mm (3/8 in. by 3/4 in.) with the 19 mm (3/4 in.) dimension along the 75 mm (3 in.) centerline. Post clip bolts shall be J-bolts, stainless steel, type 305 or 304, 9 mm by 50 mm (5/16 in. by 2 in.) 18 NC threads with 10 mm (3/8 in.) stainless steel flat and lock washers, and 8 mm (5/16 in.) 18 NC threaded hex nuts. Other fasteners may be substituted if approved. Spacing of these fasteners shall be the same as set out above for the extruded aluminum panels. Panel bolts shall be stainless steel 10 mm by 19 mm (3/8 in. by 3/4 in.) 16 NC threaded with stainless steel flat washers and hex nuts.

Trim molding shall be of the same material and gage as the panels to which it is attached.

Surface preparation shall be in accordance with 913.10(a) for metal signs. 150 mm (6 in.) sections shall be used at the top or bottom of the sign to make up signs not conforming to 0.3 m (1 ft) modules. Panels shall be bolted together on 610 mm (24 in.) centers with an allowable gap of no more than 2 mm (1/16 in.) between units. Panels shall be braced with suitable metal angles or 50 by 100 mm (2 by 4 in.) wood supports, which shall be removed after signs have been erected. Surface preparation for plywood signs shall be in accordance with the paint or reflective sheeting manufacturer's recommendations.

(c) Flexible Roll-Up Prismatic Reflective Sign. The flexible roll up prismatic reflective sign shall consist of a vinyl microprism reflective sheeting heat sealed, in a grid pattern not to exceed 32 mm (1 1/4 in.), to a vinyl coated fabric backing with a cross brace assembly and attaching fasteners. The reflective face and backing shall both be ultraviolet light stabilized and of the same color.

1. Reflectivity. The prismatic reflective sheeting shall have the following minimum reflective intensity values at 0.2 of a degree and 0.5 of a degree divergence expressed as average candelas per lux per square meter (candlepower per footcandle per square foot) of material. Measurements shall be conducted in accordance with ASTM E 809 with a test distance of 15 m (50 ft), at entrance angles of -4 and 30 degrees, and a photoreceptor angular aperture and source angular aperture of 0.1 of a degree. Projector exit aperture shall be a circle with a diameter of 25 mm (1 in.). Retroreflector reference center shall be the center of the sample tested, and retroreflector reference angle shall be 90 degrees. The datum mark shall be placed in accordance with the manufacturer's instructions.

**MINIMUM REFLECTIVE INTENSITY VALUES FOR
PRISMATIC REFLECTIVE SHEETING**

Divergence Angle (p)	Incidence Angle (p)	Orange
0.2	-4	70
0.2	+30	30
0.5	-4	50
0.5	+30	17

2. Color. The diffused day value of the orange sheeting shall be determined in accordance with 913.10(d)1b, except the sheeting shall have a minimum Y Reflectance Limit of 8.0.

3. Sheeting. The reflective sheeting shall consist of corner cube prismatic elements bonded to a flexible transparent weatherproof plastic having a smooth surface and encapsulated by a protective plastic backing. The sheeting shall contain no less than 6,200 microscopic cube corner prisms per 100 mm² (40,000 prisms per sq in.). The reflective sheeting shall have an 85 degree specular gloss of not less than 175 when tested in accordance with ASTM D 523.

The sheeting shall permit color processing with compatible transparent and opaque process inks at temperatures of 16p C to 39p C (60p F to 100p F) and relative humidity at 20 to 80 percent. The sheeting shall be heat resistant and permit force curing without staining of applied or unapplied sheeting at temperatures as recommended by the manufacturer.

The sheeting, conditioned for 24 hours at 22p ± 1p C (72p ± 2p F) and 50 ± 5 percent relative humidity, shall be sufficiently flexible to show no cracking when bent in one second's time around a 3 mm (1/8 in.) mandrel with backing contacting the mandrel.

The sheeting shall have a minimum tensile strength of 1.8 MPa (260 psi) and a minimum modulus of elasticity of 11.0 MPa (1,600 psi) when tested in accordance with ASTM D 882.

4. Durability. The reflective material shall be weather resistant and, following cleaning, shall show no appreciable discoloration, cracking, blistering, or dimensional change and shall not have less than 70 percent of the specified minimum reflective intensity values when subjected to accelerated weathering for 250 hours, in accordance with ASTM G 23, method 1, with humidity off, using type E or EH apparatus. Colorfastness shall be in accordance with 912.10(d)1e.

5. Impact Resistance. Impact resistance shall be in accordance with 913.10(d)1f.

6. Sign Face Backing Fabric. The backing fabric used to produce flexible roll-up reflective signs shall be coated on both sides with polyvinyl chloride or other approved material of the same color as the sign face. The backing fabric shall meet the following minimum requirements:

- a. A base fabric shall have a fiber of 1,000 Denier polyester; a weight of 102 g/m² (3 oz. per sq yd); and a fabric count of 10 warp and 10 fill.
- b. A coated fabric shall have a total weight of 492 g/m² (14.5 oz. per sq yd) and a distribution of 60 face and 40 back.
- c. The mechanical properties shall be tested in accordance with Federal Standard 191, method 5100. The test results shall be as follows:

	Warp	Fill
Tensile Strength (grab lbs)	Min. 980 N (220 grab lbs)	Min. 712 N (160 grab lbs)
Elongation at break (7%)	Min. 30	Min. 26

7. Cross Brace Assembly and Attaching Fasteners. Cross braces shall be constructed of glass reinforced resin or other suitable material to provide enough strength for the sign to withstand 64 km/hr (40 mph) winds without causing sign material to distort enough to affect legibility of the sign. Cross brace material shall be ultraviolet light stabilized.

Cross brace ends must be rounded to prevent splintering, sharp edges or damage to sign face. Cross braces shall be fastened at their centers with a suitable connector. The 2 braces must be separated by a flat washer or other approved separating hardware. The head of the bolt which holds the braces at the center shall face the sign.

The cross braces shall be attached to the back of the flexible roll-up sign with fasteners made of corrosion resistant material by means that shall allow as flat a profile as possible. A cross brace fastener shall be located in each of the 4 corners.

8. General Characteristics and Packaging. The flexible roll up prismatic reflective signs shall be of good appearance, free from ragged edges, cracks, and extraneous materials. A maximum of one splice is permitted in the reflective sheeting material and no splices are permitted in the fiber backing material in each roll-up sign. All splices on the fabricated roll-up signs shall be suitable for processing as supplied. Wrinkling, streaking, and mottling apparent under normal viewing conditions will not be permitted.

The roll-up signs stored in accordance with manufacturer's instructions shall be suitable for use at least one year after purchase without degradation in color and retroreflectance.

Completed signs shall be packaged in accordance with commercially accepted standards.

9. Basis of Use. Material furnished under this specification shall be covered by a type C certification in accordance with 916.

470 **(d) Reflective Sheeting.** Three types of reflective sheeting shall be used for signs and channelizing devices. Enclosed lens (engineer grade) and encapsulated lens (high intensity) reflective sheeting shall be used on signs and delineators, and barricades. flexible encapsulated lens reflective sheeting shall be used on plastic drums, flexible delineator posts, and other flexible channelizers.

1. General. Reflective sheeting shall consist of spherical lens elements within a transparent plastic having a smooth, flat surface. The sheeting shall be weather resistant and have a protected precoated adhesive backing.

480 **a. Reflectivity.** Reflective sheeting shall have minimum specified reflective intensity values for the respective type of sheeting at 0.2 degree and 0.5 degree divergence expressed as average candelas per lux per square meter (candlepower per footcandle per square foot) of material. Measurements shall be conducted in accordance with standard testing procedures for reflex reflectors in accordance with Federal Specifications L-S-300C, "Sheeting and Tape, Reflective, Non-exposed Lens, Adhesive Backing".

490 The primary color of the reflective background sheeting on certain signs shall be accomplished by the reverse screen method whereby a transparent colored ink is applied in a thin film to the face of white reflective sheeting to produce the reflectorized background color. When reverse screened transparent colored inks are applied over reflective sheeting, the reflective intensity value for enclosed lens reflective sheeting shall be at least the value listed as the minimum for the manufactured color. For all other types of sheeting, the reflective intensity value shall be at least 70 percent of the value listed for the manufactured color. Reversed screen processing shall be accomplished with inks and procedures as recommended by the manufacturer of the sheeting used.

500 **b. Color.** The diffuse day color of the reflective sheeting shall be determined in accordance with ASTM E 97. Colors shall be in accordance with Table 2. Geometric characteristics shall be confined to illumination incident within 10 degrees of and centered about a direction 45 degrees from the perpendicular to the test surface and viewing shall be within 15 degrees of and centered about the perpendicular to the test surface. Conditions of illumination and observation shall not be interchanged. The test apparatus shall be calibrated and standardized in accordance with the manufacturer's recommended procedure.

c. Adhesive. The reflective sheeting shall include a precoated, pressure sensitive adhesive backing, Class 1, or a tack free, heat activated adhesive backing, Class 2, either of which may be applied without necessity of additional adhesive coats on either the reflective sheeting or application surface.

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The Class 1 adhesive backing shall be a pressure sensitive adhesive of the aggressive tack type requiring no heat, solvent or other preparation for adhesion to smooth clean surfaces. The Class 2 adhesive backing shall be a tack free adhesive activated by applying heat in excess of 80p C (175p F) to the material as in the heat vacuum process of sign fabrication, requiring no solvent or additional preparation to smooth clean surfaces.

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The protective liner attached to the adhesive shall be removed by peeling without soaking in water or other solvents without breaking, tearing, or removing any adhesive from the backing. The protective liner shall be easily removed following accelerated storage for 4 hours at 71p C (160p F) under a weight of 17.2 kPa (2.5 psi).

When applied to a smooth aluminum surface and tested as specified in Federal Specification L-S-300C, Paragraph 4.4.4., the adhesive backing of the reflective sheeting shall produce a bond to support a 0.8 kg (1 3/4 lbs) weight for 5 minutes without the bond peeling for a distance of more than 50 mm (2 in.).

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d. Sheeting. The sheeting shall permit cutting and color processing with compatible transparent and opaque process inks at temperatures of 16p C to 38p C (60p F to 100p F) and relative humidity at 20 to 80 percent. The sheeting shall be heat resistant and permit force curing without staining of applied or unapplied sheeting at temperatures as recommended by the manufacturer.

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A 230 by 230 mm (9 in. by 9 in.) reflective sheeting specimen with liner shall be conditioned a minimum of one hour at 22p \pm 1p C (72p \pm 2p F) and 50 \pm 5 percent relative humidity. The liner shall be removed and the specimen placed on a flat surface with the adhesive side up. Ten minutes after the liner is removed and again after 24 hours, the specimen shall be measured to determine the amount of dimensional change. The reflective sheeting shall not shrink in any dimension more than 0.8 mm (1/32 in.) in 10 minutes nor more than 3 mm (1/8 in.) in 4 hours. The reflective sheeting shall possess stable and durable spherical lens elements which, following extraction, shall show no deterioration following submersion in a 5N solution of sulfuric acid for 30 minutes at 22p \pm 1p C (72p \pm 2p F).

e. Durability. Reflective material shall be weather resistant and following cleaning, shall show no appreciable discoloration, cracking, blistering, or dimensional change.

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One of the specimens prepared and subjected to accelerated weathering shall be used to test for colorfastness. Wet the specimen with a mild detergent and water solution and compare it visually with a similarly treated unexposed specimen under natural, North Sky daylight, or artificial daylight having a color temperature of 7500 K. The colorfastness will be evaluated as follows:

Excellent — No appreciable change in color.

Good — Perceptible, but no appreciable change in color.

Fair — Appreciable change in color.

Appreciable change in color means a change that is immediately noticeable in comparing the exposed specimen with the original comparison specimen. If closer inspection or a change of angle of light is required to make apparent a slight change in color, the change is not appreciable. The reflective material must show good colorfastness, or better.

The sheeting surface of sign background shall be refurbished in the following manner. Preparation shall include the removal of all demountable copy and legends within the sign border. Cleaning shall accomplish the removal of all foreign material from the sheeting surface. If patching of the sheeting is required, this will be accomplished prior to the clear coating. All copy and legends shall be remounted after the clear coating.

f. Impact Resistance. A test specimen shall be prepared by applying sheeting material according to the manufacturer's recommendations to a cleaned, etched 1 mm by 75 mm by 125 mm (0.040 in. by 3 in. by 5 in.) panel of aluminum in accordance with ASTM B 209M (ASTM B 209), alloy 6061-T6. The specimen shall be conditioned for 24 hours at $22\text{p} \pm 1\text{p}$ C ($72\text{p} \pm 2\text{p}$ F) and 50 ± 5 percent relative humidity. It shall show no cracking when the face of the panel is subjected to an impact of a 0.9 kg (2.0 lb) weight with a 16 mm (5/8 in.) rounded tip dropped from a 1.3 N m (10 inch pound) setting on a Gardner Variable Impact Tester, 1G-1120.

g. General Characteristics and Packaging. The reflective sheeting as supplied shall be free from ragged edges, cracks, extraneous materials, and shall be furnished in either rolls or sheets. When the reflective sheeting is furnished in continuous rolls, the average number of splices shall be no more than 3 per 46 m (50 yd) of material with a maximum of 4 splices in any 46 m (50 yd) length. Splices shall be suitable for continuous application.

Rolls shall be packed snugly in corrugated fiberboard boxes in such manner that no damage or defacement may occur to the reflective sheeting during shipment or storage. Rolls 75 mm (3 in.) in width to 305 mm (12 in.) in width shall be packed in corrugated fiberboard cartons of minimum 91 kg (200 lb) test. Rolls 330 mm (13 in.) in width to 600 mm (24 in.) in width shall be packed in corrugated fiberboard cartons of 125 kg (275 lbs) test. Rolls 635 mm (25 in.) in width and above shall be packed in corrugated fiberboard cartons of minimum 160 kg (350 lbs) test. Rolls wider than 150 mm (6 in.) and 9 m (10 yd) or longer in length shall be supported and suspended by the roll core within the cartons by means of plugs within built up and reinforced corrugated pads. Cut sheets shall be packaged flat between pressed composition boards or corrugated pads of the same dimensions as the sheets and shall be so packed as to prevent damage or defacement during shipment or storage.

Stored under normal conditions, the reflective sheeting shall be suitable for use for a period of at least one year.

600

2. Enclosed Lens, Engineer Grade, and Super Engineer Grade, Reflective Sheeting. The sheeting shall consist of spherical lens elements embedded within a transparent plastic having a smooth, flat surface. The sheeting shall be weather resistant and have a protected precoated adhesive backing.

a. Reflectivity. The reflective sheeting shall have the following minimum reflective intensity values.

**MINIMUM REFLECTIVE INTENSITY VALUES FOR ENCLOSED
ENGINEERED GRADE LENS SHEETING**

610

Divergence Angle (°)	Incidence Angle (°)	White	Green	Yellow	Red	Orange	Blue	Brown
0.2	-4	70	9	50	14.5	25	4.0	1
0.2	+30	30	3.5	22	6	7	1.7	0.3
0.5	-4	30	4.5	25	7.5	13.5	2	0.35
0.5	+30	15	2.2	13	3	4	0.8	0.20

SUPER ENGINEER GRADE

620

Divergence Angle (°)	Incidence Angle (°)	White	Green	Yellow	Red	Orange	Blue	Brown
0.2	-4	140	30	100	30	60	10	5
0.2	+30	60	10	36	12	22	4	2
0.5	-4	50	9	33	10	20	3	2
0.5	+30	28	6	20	6	12	2	1

b. Color. The diffuse day value of the sheeting shall be determined in accordance with 913.10(d)1b.

630

**TABLE 1 - COLOR SPECIFICATIONS LIMITS AND REFERENCE
STANDARDS FOR ENCLOSED LENS SHEETING**

	Chromaticity Coordinates (Corner Points)							
	1		2		3		4	
	X	Y	X	Y	X	Y	X	Y
Silver-White	.305	.290	.350	.342	.321	.361	.276	.308
Yellow	.482	.450	.532	.465	.505	.494	.475	.485
Red	.602	.317	.664	.336	.644	.356	.575	.356
Green	.130	.369	.180	.391	.155	.460	.107	.439
Blue	.147	.075	.175	.091	.176	.151	.106	.113
Orange	.535	.375	.607	.393	.582	.417	.535	.399
Brown	.445	.353	.604	.396	.556	.443	.445	.386

640

**TABLE 1 - COLOR SPECIFICATIONS LIMITS AND REFERENCE
STANDARDS FOR ENCLOSED LENS SHEETING**

	Reflectance Limit		Ref. Std. MUNSELL PAPERS
	Y		
	Min.	Max.	
Silver-White	35.0	—	6.3GY 6.77/0.8
Yellow	29.0	45.0	1.25Y 6/12
Red	8.0	12.0	8.2R 3.78/14.0
Green	3.5	9.0	0.65BG 2.84/8.45
Blue	1.0	4.0	5.8PB 1.32/6.8
Orange	18.0	30.0	2.5YR 5.5/14.0
Brown	4.0	9.0	5YR 3.6

650

c. Adhesive. The adhesive shall be in accordance with 913.10(d)1c.

d. Sheeting. The 85 degree specular gloss of the reflective sheeting shall be a minimum of 40 when tested in accordance with ASTM D 534.

660

A test specimen shall be prepared by applying sheeting according to the manufacturer's recommendations to a clean, etched 0.51 by 50 by 200 mm (0.020 in. by 2 in. by 8 in.) panel of aluminum in accordance with ASTM B 209M (ASTM B 209), alloy 6061-T6. The specimen shall be conditioned a minimum of 48 hours and tested at $22\text{p} \pm 1\text{p}$ C ($72\text{p} \pm 2\text{p}$ F) and 50 ± 5 percent relative humidity. It shall show no cracking when bent around a 19 mm (3/4 in.) mandrel.

e. Durability. Reflective material shall not have less than 50 percent of the specified minimum reflective intensity values for enclosed lens sheeting when subjected to accelerated weathering for 1000 hours in accordance with ASTM G 23, method 1 with humidity off, using type E or EH apparatus, and operation schedule of Federal Test Method Standard 141a, method 6151, Paragraph 4.1.1.

f. Impact Resistance. Impact resistance shall be in accordance with 913.10(d)1f.

g. General Characteristics and Packaging. The general characteristics and packaging shall be in accordance with 913.10(d)1g.

3. Encapsulated Lens, High Intensity, Reflective Sheeting. The high intensity reflective sheeting shall consist of spherical lens elements adhered to a synthetic resin and encapsulated by a flexible, transparent, weatherproof plastic having a smooth surface. The sheeting shall have a precoated adhesive backing protected by a treated plastic liner.

a. Reflectivity. The high intensity reflective sheeting shall have the following minimum reflective intensity values.

**MINIMUM REFLECTIVE INTENSITY VALUES FOR
ENCAPSULATED LENS SHEETING**

Divergence Angle (p)	Incidence Angle (p)	White	Green	Yellow	Red	Orange	Blue
0.2	-4	250	45	170	45	100	20
0.2	+30	150	25	100	25	60	11
0.5	-4	95	15	62	15	30	7.5
0.5	+30	65	10	45	10	25	5

Reflective sheeting for all sign copy, including letters, numerals, symbols, borders, and route markers used on high intensity reflective sheeting background, shall be high intensity white.

b. Color. The diffuse day value of the sheeting shall be determined in accordance with 913.10(d)1b, except the sheeting shall be in accordance with Table 2.

**TABLE 2 - COLOR SPECIFICATIONS LIMITS AND REFERENCE
STANDARDS FOR REFLECTIVE SHEETING**

	Chromaticity Coordinates (Corner Points)							
	1		2		3		4	
	X	Y	X	Y	X	Y	X	Y
White	.303	.287	.368	.353	.340	.380	.274	.316
Green	.030	.380	.166	.346	.286	.428	.201	.776
Yellow	.498	.412	.557	.442	.479	.520	.438	.472
Red	.613	.297	.708	.292	.636	.364	.558	.352
Orange	.550	.360	.630	.370	.581	.418	.516	.394
Blue	.144	.030	.244	.202	.190	.247	.066	.208
Brown	.430	.340	.610	.390	.550	.450	.430	.390

**TABLE 2 - COLOR SPECIFICATIONS LIMITS AND REFERENCE
STANDARDS FOR ENCAPSULATED LENS SHEETING**

	Reflectance Limit		Ref. Std. MUNSELL PAPERS
	Y		
	Min.	Max.	
White	27.0	—	5PB 7/1
Green	3.0	9.0	10G 3/8
Yellow	15.0	45.0	1.25Y 6/12
Red	2.5	15.0	7.5R 3/12
Orange	7.0	30.0	2.5YR 5.5/14
Blue	1.0	10.0	5.8PB 1.32/6.8
Brown	1.0	9.0	5YR 3/6

c. Adhesive. The adhesive shall be in accordance with 913.10(d)1c.

d. Sheeting. The 85 degree specular gloss of the reflective sheeting shall be a minimum of 50 when tested in accordance with ASTM D 523.

Color processing for encapsulated lens material shall be restricted to sheeting with heat activated adhesive backing unless otherwise recommended by the manufacturer.

The sheeting with the liner removed and conditioned for 24 hours at $22\text{p} \pm 1\text{p}$ C ($72\text{p} \pm 2\text{p}$ F) and 50 ± 5 percent relative humidity, shall be sufficiently flexible to show no cracking when bent within one second around a 3 mm (1/8 in.) mandrel with adhesive contacting the mandrel.

e. Durability. All colors of the reflective material, except orange, shall have not less than 80 percent of the specified minimum intensity values for encapsulated lens sheeting when subjected to accelerated weathering for 2200 hours in accordance with ASTM G 23, method 1 with humidity off, using Type E or EH apparatus, and operation schedule of Federal Test Method Standard 141a, method 6151, Paragraph 4.1.1. Orange reflective sheeting shall conform to the same requirements, except the accelerated weathering shall be 500 hours instead of 2200 hours. Colorfastness shall be in accordance with 913.10(d)1e.

750

f. Impact Resistance. Impact resistance shall be in accordance with 913.10(d)1f.

g. General Characteristics and Packaging. Wrinkling, streaking and mottling apparent under normal viewing conditions will not be permitted.

4. Flexible Encapsulated Lens Reflective Sheeting, High Intensity. This sheeting shall be for use on flexible delineating or channelizing devices where flexing and bending is anticipated. The description of this sheeting shall be in accordance with 913.10(d)3.

760

a. Reflectivity. The reflectivity shall be in accordance with 913.10(d)3a.

b. Color. The color shall be in accordance with 913.10(d)3b.

c. Adhesive. The adhesive shall be a pressure sensitive adhesive, Class 1 in accordance with 913.10(d)1c, except the adhesive backing of the flexible reflective sheeting shall produce a bond to support a 0.8 kg (1 3/4 lb) weight for 5 minutes, without the bond peeling for a distance of more than 25 mm (1.0 in.) when applied to a smooth aluminum surface and tested as specified in Federal Specifications L-S-300C, Paragraph 4.4.4.

770

d. Sheeting. The sheeting shall be in accordance with 913.10(d)3d with the exception of the following:

780

- (1) A 229 mm by 229 mm (9 in. by 9 in.) reflective sheeting specimen with liner shall be conditioned a minimum of one hour at $22\pm 1^\circ\text{C}$ ($72\pm 2^\circ\text{F}$) and 50 ± 5 percent relative humidity. The liner shall be removed and the specimen placed on a flat surface with the adhesive side up. Ten minutes after the liner is removed and again after 24 hours, the specimen shall be measured to determine the amount of dimensional change. The reflective sheeting shall not shrink in any dimension more than 0.8 mm (1/32 in.) in 10 minutes nor more than 2.5 mm (1/10 in.) in 24 hours.

- (2) The sheeting, with the liner removed and conditioned for 24 hours at $-18\text{p} \pm 1\text{p}$ C ($0\text{p} \pm 2\text{p}$ F) and 50 ± 5 percent relative humidity, shall be sufficiently flexible to show no cracking when bent in one second's time around a $1/8$ of an inch (3.2 mm) mandrel with adhesive contacting the mandrel.

e. Durability. All colors of the flexible reflective material shall have a minimum 70 percent of the specified minimum intensity values for encapsulated lens reflective sheeting when subjected to accelerated weathering for 500 hours in accordance with ASTM G 23, method 1 with humidity off, using type E or EH apparatus. Colorfastness shall be in accordance with 913.10(d)1e.

f. Impact Resistance. Impact resistance shall be in accordance with 912.10(d)1f, except the flexible reflective sheeting shall be conditioned at $0\text{p} \pm 2\text{p}$ F ($-18\text{p} \pm 1\text{p}$ C) and 50 ± 5 percent relative humidity prior to impact testing.

g. General Characteristics and Packaging. The flexible reflective sheeting and packaging shall be in accordance with 912.10(d)3g.

5. Prismatic Lens, High Intensity, Reflective Sheeting. Prismatic lens high intensity reflective sheeting shall consist of prismatic lens elements which shall be adhered and formed in a transparent synthetic resin, sealed, and backed with a pressure-sensitive adhesive and a plastic liner.

a. Reflectivity. The prismatic lens reflective sheeting shall have the following minimum reflective intensity values.

**MINIMUM REFLECTIVE INTENSITY VALUES FOR
PRISMATIC LENS SHEETING**

Divergence Angle, Deg.	Incidence Angle, Deg.	White	Green	Yellow	Red	Orange	Blue	Brown
0.1	-4	400	56	270	56	160	32	12
0.1	+30	120	13	75	13	48	7	3
0.2	-4	250	35	170	35	100	20	7
0.2	+30	80	9	54	9	34	5	2
0.5	-4	135	17	100	17	64	10	4
0.5	+30	55	6.5	37	6.5	22	3.5	1.4

b. Color. The diffused day value of the sheeting shall be determined in accordance with 913.10(d)1b. The sheeting shall be in accordance with Table 2.

830 **c. Adhesive.** The adhesive shall be in accordance with 913.10(d)1c.

d. Sheeting. The 85 degree specular gloss of the reflective sheeting shall be a minimum of 50 when tested in accordance with ASTM D 523.

840 Color processing for the sheeting shall permit cutting and color processing with compatible transparent and opaque process colors in accordance with the sheeting manufacturer's recommendations at temperatures of 15p C to 38p C (59p F to 100p F) and relative humidities of 20 to 80 percent. The sheeting shall be heat resistant and shall permit force curing without staining of applied or unapplied sheeting at temperatures recommended by the sheeting manufacturer.

The sheeting, with the liner removed and conditioned for 24 hours at 22 pC \pm 1p C (72p F \pm 2p F) and 50 \pm 5 percent relative humidity, shall be sufficiently flexible to show no cracking when bent within one second around a 3 mm 1/8 in.) mandrel with adhesive contacting the mandrel.

e. Durability. The durability shall be in accordance with 913.10(d)3e.

850 **f. Impact Resistance.** Impact resistance shall be in accordance with 913.10(d)1f.

g. General Characteristics and Packaging. Wrinkling, streaking, and mottling which are apparent under normal viewing conditions will not be permitted.

6. Prismatic Lens, Super High Intensity, Reflective Sheeting. Prismatic lens super high intensity reflective sheeting shall consist of cube corner prismatic lens elements which shall be adhered and formed in a transparent synthetic resin, sealed, and backed with a pressure-sensitive adhesive and a plastic liner.

860 **a. Reflectivity.** The prismatic lens reflective sheeting shall have the following minimum reflective intensity values.

Divergence Angle, Deg.	Incidence Angle, Deg.	White	Green	Yellow	Red	Orange	Blue
0.2	-4	800	80	660	215	200	43
0.2	+30	400	35	340	100	120	20
0.5	-4	200	20	160	45	80	9.8
0.5	+30	100	10	85	26	50	5.0

870 **b. Color.** The diffused day value of the sheeting shall be determined in accordance with 913.10(d)1b. The sheeting shall be in accordance with Table 2.

c. Adhesive. The adhesive shall be in accordance with 913.10(d)1c.

d. Sheeting. The sheeting shall be in accordance with 913.10(d)5d.

880 **e. Durability.** All colors for reflective material, except orange, shall have not less than 50 percent of the specified minimum intensity value for prismatic lens sheeting when subjected to accelerated weathering for 2,200 hours in accordance with ASTM G 23, Method 1 with humidity off, using type E or EH apparatus, and operation schedule of Federal Test Method Standard 141a, Method 6151, Paragraph 4.1.1. Orange reflective sheeting shall be in accordance with the same requirements. However, the accelerated weathering shall be 1,000 hours instead of 2,200 hours. Colorfastness shall be in accordance with 913.10(d)1e.

f. Impact Resistance. Impact resistance shall be in accordance with 913.10(d)1f.

890 **g. General Characteristics and Packaging.** Wrinkling, streaking, and mottling which are apparent under normal viewing conditions will not be permitted.

(e) Letters, Numerals, Symbols, and Accessories.

900 **1. Embossed Reflective Sheeting Type.** Embossed reflective sheeting type shall be in accordance with the AASHTO standards for use on the National System of Interstate and Defense Highways. The reflective sheeting shall be mechanically applied to the properly prepared aluminum with the equipment and in a manner prescribed by the sheeting manufacturer. Letters, numerals, and symbols shall be 1.02 mm (0.040 in.) thick aluminum sheets in accordance with ASTM B 209M (ASTM B 209), alloy 3003-H14. Borders shall be 0.81 mm (0.032 in.) thick aluminum sheet in accordance with ASTM B 209M (ASTM B 209), alloy 6061-T6. All units shall have an embossed height of approximately 3 mm (1/8 in.). Spacing of mounting holes for screws, bolts, or rivets shall be determined by character size and shape but in no case shall not be more than 20 mm (8 in.) on center.

Completed demountable units shall be dip coated with a full glossy coat of finishing clear as specified and supplied by the sheeting manufacturer. The finished units shall show careful workmanship and be clean cut, sharp, and have essentially a plane surface.

910 **2. Acrylic Plastic Type.** Acrylic plastic type shall consist of embossed aluminum frames in which prismatic reflectors are installed so as to be an integral part of the character or otherwise affixed to prevent their displacement in handling or service. Reflectors which are held in the frames by means of tape or adhesive will not be accepted. All units shall be in accordance with AASHTO standards for use on the National System of Interstate and Defense Highways. All items shall be fabricated from 1 mm (0.040 in.) sheet aluminum in accordance with, ASTM B 209M (ASTM B 209), alloy 3003-H14. Mounting holes shall be provided within the frames to permit the use of screws, rivets, or other common fasteners. The size and spacing of reflector holes shall be such as to afford maximum night legibility and visibility to the finished cut-out figure.

The reflectors shall consist of a clear and transparent plastic face, herein referred to as the lens, and an opaque back fused to the lens, under heat and pressure, around the entire perimeter to form a homogeneous unit permanently sealed against dust, water, and water vapor. The reflector shall be colorless, yellow, red, or green, as specified. The lens shall consist of a smooth front surface free from projections or indentations other than for identification and a rear surface bearing a prismatic configuration such that it will effect total internal reflection of light. The manufacturer's trademark shall be molded legibly into the face of the lens.

930

The specific brightness of each reflex reflector intended for use in cutout letters, symbols, and accessories shall be equal to or exceed the following minimum values with measurements made with reflectors spinning. Five reflectors shall be submitted for test for brightness. Area of the reflector will be calculated on the exposed surface within the frame. Failure of one or more subjected to test shall constitute failure of the lot.

940

Observation Angle, Degrees	Entrance Angle, Degrees	Specified Brightness candela per m ² per lux (candlepower per in. ² per footcandle)
1/10	0	2016 (14.0)
1/10	20	806 (5.6)
1/6	0	1440 (10.0)
1/6	20	576 (4.0)
1/3	0	1008 (7.0)
1/3	20	403 (2.8)

For yellow reflectors the specific brightness minimum shall be 60 percent. For red and green it shall be 25 percent of the value shown for crystal.

950

The following test shall be used to determine if a reflector is adequately sealed against dust and water. Submerge 5 samples in a water bath at room temperature. Subject the submerged samples to a vacuum of 125 mm (5 in.) of mercury, gage, for 5 minutes. Release the vacuum and let samples stand submerged for another 5 minutes. Remove samples and examine for water intake. Failure of one or more shall constitute failure of the lot. Three reflectors shall be tested for 4 hours in a circulating air oven at 52 ± 3 °C (125 ± 5 °F). The test specimens shall be placed in a horizontal position on a grid or perforated shelf permitting free air circulation. At the conclusion of the test the samples shall be removed from the oven and permitted to cool in air to room temperature. The samples, after exposure to heat, shall show no significant change in shape and general appearance when compared with unexposed control standards. No failure will be permitted. The assembled cut out letter, symbol, or accessory shall withstand the combined corrosion test in accordance with ASTM B 117.

960

Each cut out figure, completely assembled with reflectors, shall be supplied in an individual package with contents marked thereon.

(f) Fiberglass Reinforced Plastic Sign Panels. Fiberglass reinforced plastic sign panels will be permitted as an alternate to aluminum sign panels up to and including a thickness of 2.54 mm (0.100 in.). The sign size will be limited to a maximum of 1220 mm by 1220 mm (48 in. by 48 in.). Fiberglass reinforced plastic shall be new and shall be in accordance with the requirements herein.

Fiberglass reinforced plastic sign panel material shall be a fiberglass reinforced thermoset polyester laminate. The panel shall be acrylic modified and UV stabilized for outdoor weatherability. The panel shall be stabilized to prevent the release of migrating constituents such as solvents or monomers over time. The panel shall contain no residual release agents on the surface of the laminate so that neither migrating constituents nor release agents shall be present in amounts that interfere with the bonding between the laminate and the reflective sheeting. The panel shall not contain visible cracks, pinholes, foreign inclusions, or surface wrinkles which affect the designed purpose or implied performance, alter the specific dimensions, or otherwise affect the serviceability.

1. Mechanical Properties. The following mechanical properties will be minimum requirements and shall be measured in both the line direction of the panel and at 90 degrees to the line as noted in the referenced ASTM test.

Mechanical Properties	Minimum Requirement, Mpa (psi)	ASTM Test
Tensile Strength	70 MPa (10,000)	D 638M (D 638)
Tensile Modulus	8275MPa (1,200,000)	B 638
Flexural Strength	138 MPa (20,000)	D 790M (D 790)
Flexural Modulus	8275 MPa (1,200,000)	D 790M (D 790)
Compression Strength	220 MPa (32,000)	D 695M (D 695)
Compression Modulus	9650 MPa (1,400,000)	D 695M (D 695)
Punch Shear	890 MPa (13,000)	D 732

2. Physical Properties. Fiberglass reinforced plastic panels shall be in accordance with physical properties shown below.

a. Thickness. The panel shall be 3.43 mm (0.135 in.) thick with a tolerance of ± 0.13 mm (± 0.005 in.).

b. Length and Width. Panels shall be measured in accordance with ASTM D 3841 for the purpose of determining this physical property. The tolerance for each panel length and width shown in the Schedule of Pay Items shall be in accordance with the requirements as follows:

(1) Panel Length of 3660 mm (144 in.) or Less. The tolerance shall be ± 3 mm ($\pm 1/8$ in.) of the nominal length.

1010

(2) Panel Length Exceeding 3660 mm (144 in.). The tolerance shall be ± 3 mm ($\pm 1/8$ in.) per 3.7 m (12 ft) increment of length, ± 3 mm ($\pm 1/8$ in.) per remaining incremental length of less than 3.7 m (12 ft).

(3) Panel Width of 3660 mm (144 in.) or Less. The tolerance shall be ± 3 mm ($\pm 1/8$ in.) of nominal width.

c. Squareness. The panel shall be within ± 3 mm ($\pm 1/8$ in.) of square per 3.7 m (12 ft) of length when measured in accordance with ASTM D 3841.

1020

d. Weather Resistance. The panel shall be classified as a minimum grade II weather resistant panel as specified in ASTM D 3841 following a $3,000 \pm 100$ hour weatherometer test.

e. Fire Resistance. The extent of burning of the panel shall not exceed 25 mm (1.0 in.) when tested in accordance with ASTM D 635.

f. Impact Resistance. The panel shall resist the impact of a 0.54 kg (1.18 lb) ball dropped from 18.3 m (60 ft) in accordance with ASTM D 3841.

1030

g. Coefficient of Linear Thermal Expansion. The panel strength and impact resistance shall not be affected over a temperature range of -54°C to 100°C (-65°F to 212°F). The panels shall have a maximum coefficient of linear thermal expansion of $0.000306 \text{ mm/mm/}^{\circ}\text{C}$ ($0.000018 \text{ in./in./}^{\circ}\text{F}$) when tested in accordance with ASTM D 696.

h. Panel Smoothness. The panel shall be manufactured with smooth surfaces on both the top and bottom of the panel.

i. Flatness. Panels shall have a maximum deflection of 13 mm (0.5 in.) when tested as shown below.

1040

(1) Test Purpose. This test shall be performed to determine the potential for warpage in fiberglass reinforced plastic panels.

(2) Test Procedure. This test will require five 760 mm by 760 mm (30 in. by 30 in.) fiberglass reinforced panels. Initial warpage shall be measured in 4 directions: 0 degrees, 45 degrees, 90 degrees, and 135 degrees. To measure warpage, the panel shall be freely suspended at one corner. A straightedge shall be placed along the panel so that the edges of the panel touch the straightedge. The dimensional characteristics of the panel shall not be disturbed. A rule graduated in fractional millimeters (inches) shall be used to measure the distance from the center of the panel face to the straightedge. Such distance shall be measured to the nearest 0.80 mm ($1/32$ in.) in all 4 directions.

1050

The panel shall be freely suspended diagonally in an oven for 48 hours at 82p C (180p F). After 48 hours in the oven, the panels shall be removed and permitted to cool in free suspension at room temperature. Warpage measurements and corresponding direction shall again be recorded as described above.

1060 **j. Color.** The panel shall be pigmented to a visually uniform gray color within the Munsel R range of N.7.5/ to N.8.5/.

(g) Samples and Tests.

1070 **1. Reflective Sheeting.** Each series and color of reflective sheeting will be tested, evaluated, and approved prior to use. A list of approved manufacturers' series and colors will be maintained by the Department. Only reflective sheeting series and colors from the List of Approved or Prequalified Materials in effect as of the date of letting shall be used in the contract. Manufacturers desiring evaluation of their reflective sheeting material shall contact the Evaluation Unit at the Procurement and Distribution Division to make arrangements to begin the evaluation process.

Reflective sheeting which is furnished under this specification shall be covered by a type C certification in accordance with 916.

1080 **2. Traffic Signal Materials.** Materials furnished under this specification with the exception of fiberglass reinforced plastic sign panels, shall be covered by a type C certification in accordance with 916. Fiberglass reinforced plastic sign panels shall be covered by a type B certification in accordance with 916.

913.11 Highway Illumination Materials. All luminaires, lamps, fuse kits, wire and cable, and major equipment shall be approved new material bearing the UL seal of approval or meet their standards.

Descriptive and technical literature shall be furnished for approval on all equipment prior to purchase and incorporation into the work.

Warranties for all major equipment shall be in accordance with 807.02.

1090 **(a) Lighting Standards and Mast Arms, under 80 feet (24.4 m).**

1. General Requirements. Conventional lighting standards shall be aluminum or steel and shall be in accordance with AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.

1100 For conventional light standards, design wind velocity shall be 130 km/hr (80 mph). The maximum horizontal deflection of the pole under maximum loading conditions shall not exceed a deflection angle of one degree and 10 minutes from the vertical axis of the pole for any 0.3 m (1.0 ft) section of the pole along the entire length of the pole. The maximum stress shall be 80 percent of the AASHTO Standard Specifications for

Group I-DL loads. Vibration dampers shall be furnished as recommended by the manufacturer. The manufacturer may use drag coefficients based on actual wind tunnel tests; otherwise, he shall use the drag coefficients in Table 1.2.5c of Group I loads.

1110 Conventional light standards shall be designed to support a 24 kg (53 lb) luminaire with an effective projected area of 0.22 m² (2.4 ft²). When larger luminaires are specified the light standards shall be designed to support the larger luminaires and this shall be shown on the light standard shop drawings.

1120 Conventional poles shall have a 100 by 200 mm (4 in. by 8 in.) reinforced hand-hole centered 460 mm (18 in.) above the base of the pole and a cover attached with a minimum of two stainless steel hex head bolts. The pole shall have a removable pole cap and a wire support hook to support the vertical drop of wire by a service drop clamp attached to the cable. A wiring hole with a 25 mm (1 in.) inside diameter grommet shall be provided where the arm is attached. Pole bases shall be designed for mounting on anchor bolts equally spaced on an 292 mm (11 1/2 in.) or 368 mm (14 1/2 in.) diameter anchor bolt circle. Anchor bolt covers shall be furnished.

Hardware shall be type 304 or 305 stainless steel in accordance with ASTM A 276, except where otherwise specified.

For conventional poles, a 13 mm (1/2 in.) by 13 UNC threaded grounding nut or other approved method shall be provided near the bottom of and shall be accessible through the handhole for attaching the ground wire. The ground wire shall be No. 6 AWG soft-drawn, solid copper in accordance with ASTM B 3.

1130 Mast arms less than 2.4 m (8 ft) in length shall either be single member or truss type, except that mast arms on bridge deck light standards shall be truss type. Single member arms shall be a tapered tube oval shaped at the pole end with the long dimension in the vertical plane, welded to a pole plate and bolted or clamped to the shaft with a minimum of four 13 mm (1/2 in.) bolts. Mast arms 2.4 m (8 ft) and over in length shall be truss type. The upper member shall be a tapered tube oval shaped at the pole with the long dimension in the horizontal plane. The lower member may be standard pipe. Both members shall be welded to a pole plate and bolted or clamped to the pole. A minimum of four 13 mm (1/2 in.) bolts at the upper member and a minimum of two 10 mm (3/8 in.) bolts at the lower member shall be used if a pole plate configuration is used to attach the mast arm to the pole. Mast arms that are clamped to the pole shall have a minimum of four 13 mm (1/2 in.) bolts per clamp. Mast arms shall provide an enclosed raceway for the wiring and shall be free of burrs and rough edges. Each arm shall be furnished with a 50 mm (2 in.) nominal pipe size slipfitter. The maximum rise of the truss style arm shall be as set out in the table and shall be measured vertically from the centerline of the free end of the truss to a plane through the centerline of the upper arm bracket after loading.

1140

MAST ARM LENGTH m (ft)	MAXIMUM RISE m (ft)
27 or less (9)	1.2 (4)
3 to 4.3 (10 to 14)	1.5 (5)
4.5 to 5.8 (15 to 19)	1.7 (5.5)
6.1 to 7.6 (20 to 25)	1.8 (6)
7.9 to 9.1 (26 to 30)	2.4 (8)

Light standards shall be constructed to provide a nominal luminaire mounting height above the roadway pavement as shown on the drawings. The elevations of foundations above or below the edge of the pavement shall be controlled by existing roadside conditions. The proper shaft length shall be determined by field measurement prior to placing an order for the poles.

A variation in the nominal mounting height of ± 0.3 m (1 ft) is permitted so that the "Effective Mounting Height", foundation to luminaire, of the light standards may be supplied for 12.2 m (40 ft) nominal mounting height.

Elevation of Foundation Top with Respect to the Near Road Edge m (ft)	Effective Mounting Height, Foundation to Luminaire m (ft)
+2.13 to +1.53 (7.00 to 5.01)	10.4 (34)
+1.52 to +0.92 (5.00 to 3.01)	11.0 (36)
+0.91 to +.031 (3.00 to 1.01)	11.6 (38)
+0.30 to -0.30 (+1.00 to -1.00)	12.2 (40)
-0.31 to -0.91 (-1.01 to -3.0)	12.8 (42)
-0.92 to -1.52 (-3.01 to -5.00)	13.4 (44)
-1.53 to -2.13 (-5.01 to -7.00)	14.0 (46)

The effective mounting heights for other nominal mounting heights deviate from the table by the difference in the nominal heights.

2. Aluminum Lighting Standards.

a. Round Seamless. The pole and mast arm shall be in accordance with ASTM B 241M (ASTM B 241), alloy 6063-T4, and of sufficient diameter and wall thickness to withstand the design loads. The pole shall be tapered full length or tapered in the middle with the top and/or bottom approximately 1/3 of the pole of constant cross

1190 section. The minimum wall thickness for poles on breakaway couplings and steel slip bases shall be 5.6 mm (0.219 in.). Poles on transformer bases or shoe anchor bases installed without breakaway devices are exempted from this minimum wall thickness requirement. An inner tube extension or sleeve fitted inside the main tube, shaft, is permissible to increase the wall thickness of the shaft starting at the bottom of the shoe base and extending upward towards the top of the pole. The sleeve or tube extension shall be no less than 0.9 m (3 ft) in length, fabricated from aluminum alloy 6063-T4 and heat treated to produce a T-6 temper after placing in the shaft. The minimum wall thickness of the combination of shaft and sleeve shall be 5.6 mm (0.219 in.). Attaching plates or clamps for aluminum mast arms shall be in accordance with ASTM B 241M (ASTM B 241), alloys 6061T6, 6063-T6, 356.0-T6, or 5052-H32. The bottom end of the shaft shall be welded to a one piece cast aluminum shoe anchor base of 356.0-T6 aluminum alloy in accordance with ASTM B 26M (ASTM B 26) for sand castings or ASTM B 108 for permanent mold castings or equal and provided with 4 slotted holes for anchor bolts and then the shaft's full length shall be heat treated to produce a T6 temper. The top of the shaft shall be provided with a removable aluminum pole cap. The shaft shall have no longitudinal welds. After fabrication, the shaft shall be cleaned to a satin finish and wrapped for protection during shipping and handling.

1200

b. Single Longitudinal Welded. The material for these lighting standards shall be round, tapered structural marine aluminum sheet in accordance with ASTM B 209M (ASTM B 209), alloy 5086-H34, and of sufficient diameter and wall thickness to withstand the design loads. The minimum wall thickness for poles on breakaway couplings and steel slip bases shall be 5.6 mm (0.219 in.). Poles on transformer bases or shoe anchor bases installed with no breakaway devices are exempted from the minimum wall thickness requirement. The anchor base shall be one piece cast aluminum in accordance with ASTM B 26M (ASTM B 26), alloy 356.0-T-6. The base casting for the formed and welded shaft shall be designed to be inserted a minimum of 305 mm (12 in.) into the shaft and bonded to the shaft with a weatherproof structural epoxy adhesive that fully develops the required strength as specified by the design criteria. After fabrication, the shaft shall be cleaned to a satin finish and wrapped for protection during shipping and handling.

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3. Stainless Steel Lighting Standards. Stainless steel lighting standards shall be prefabricated from stainless steel in accordance with ASTM A 412, type 201, that has a minimum yield point of 469 MPa (68,000 psi). Welds other than spot welds shall be performed with conventional welding equipment and with stainless steel welding rods. Welds shall be free of cracks and pores. The wall thickness and diameter of the pole shall be sufficient to withstand designed loads. Exposed surfaces of the standard shall be smooth and free from marks or imperfections. During shipment, the poles and mast arms shall be protected with a non-staining protective material to preserve the finish.

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4. Galvanized Steel Lighting Standards. The pole and base plate shall be fabricated from steel in accordance with ASTM A 572M (ASTM A 572) or A 595 with a minimum yield of 345 MPa (50,000 psi). Single member mast arms and the upper members of truss type mast arms shall be fabricated from steel in accordance with ASTM

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A 572M (ASTM A 572 or A 595 with a minimum yield strength of 345 MPa (50,000 psi). The lower member of truss type arm may be fabricated from standard steel pipe in accordance with ASTM A 53 with a minimum yield strength of 250 MPa (36,000 psi). After fabrication, the pole and mast arm shall be thoroughly cleaned and galvanized in accordance with ASTM A 123.

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Steel standards shall be tapered 11.67 mm/m (0.14 in./ft) and shall be round, octagonal, or dodecagonal. The design load shall be used to determine the pole diameter and wall thickness. The pole shall have one longitudinal electrically welded joint. A steel base plate shall be welded to each pole and provided with 4 slotted holes for the anchor bolts.

All welds on steel standards shall be performed at the factory. Base plate welds shall be 100 percent penetration. Circumferential welds shall be backed-up welds with 100 percent penetration. Longitudinal welds shall be a minimum of 60 percent penetration. The 100 percent penetration welds shall be ultrasonically inspected and all other welds shall be inspected by magnetic particle. Welding shall be performed in accordance with 711.32.

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5. Wood Pole Lighting Standards. Wood poles for highway lighting standards shall be in accordance with 913.15(e)2.

6. Frangible Breakaway Bases. All light standards, except high mast towers, those protected by bridge end bents or retaining walls, shall be installed on breakaway devices. All breakaway devices on a contract shall be of the same type and manufacturer.

Breakaway devices shall be in accordance with AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals as modified in 913.11(a)1.

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A certification from the manufacturer shall be furnished with the shop drawings stating the breakaway devices conform to the breakaway criteria of the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.

a. Cast Aluminum Transformer Base. The anchor bolts for transformer bases shall be as accordance with 913.11(a)7. The anchor bolt circle for transformer bases shall be 381 mm (15 in.). The bolt holes in the transformer base may be slotted. The pole shall be bolted to the transformer base with four 25 mm (1 in.) diameter galvanized steel bolts.

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An approved handhole in the transformer base may be substituted for the 100 by 200 mm (4 in. by 8 in.) handhole specified in 913.11(a)1.

b. Breakaway Coupling. Breakaway couplings may be used with aluminum poles with mounting heights up to 15 m (50 ft) and with steel poles that weigh

272 kg (600 lbs) or less. The couplings shall be furnished with necessary hardware including a 2 piece cover. Couplings shall be installed in accordance with the manufacturer's instructions and recommended clearance between the top of the foundation and the bottom of the breakaway coupling.

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7. Anchor Bolts. Anchor bolts shall be 25 mm (1 in.) with 8NC rolled threads in accordance with ASTM A 307. The minimum length of threads shall be 150 mm (6 in.). Mean diameter of rod stock shall be 23.32 mm \pm 0.28 mm (0.918 in. \pm 0.011 in.) and out-of-round tolerance shall be \pm 0.3 mm (0.012 in.). The top 254 mm (10 in.) of the bolt shall be galvanized in accordance with ASTM A 153. Anchor bolts shall be in accordance with 910.19(b). The bolts shall be a minimum of 914 mm (36 in.) in length for poles 200 mm (8 in.) outside diameter or less and 1.22 m (48 in.) in length for poles 230 mm (9 in.) or 254 mm (10 in.) outside diameter. In addition to the minimum length, the bolt shall have a 100 mm (4 in.) right angle bend at the unthreaded end. The anchor bolts in bridge structures shall be as shown on the plans.

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(b) High Mast Standards of 24.5 m (80 ft) and Over. The high mast pole, base, anchor bolts, lowering device, installed fixtures, and associated appurtenances shall be designed to withstand a minimum wind speed of 155 km/h (90 mph), gust of 188 km/h (117 mph), using applicable design criteria in accordance with the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals. Minimum design criteria for each fixture shall be an effective projected area of 0.26 m² (2.8 ft²) and a weight of 38.6 kg (85 lbs). If larger fixtures are used the actual size and weight shall be used in the design of the pole.

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The Contractor shall be responsible for the accuracy of the dimensions and the proper fit of all material and equipment furnished with the pole. The Contractor shall provide all applicable manufacturer's warranties for material and workmanship. External lowering devices shall be designed to attach to the pole as shown on the plans. The pole shall include the mounting accommodations as shown on the plans.

1. High Mast Poles. The poles shall be made of steel in accordance with ASTM A 590, ASTM A 870, or ASTM A 560 grade C. The steel shall have a minimum yield strength of 410 MPa (59,500 psi).

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All steel used in the base plate and shaft shall meet an impact property of 20.3 J (15 ft·lbs) at +4.5 °C (+40 °F) in the longitudinal direction using the Charpy V-Notch test. This shall be an average of 3 tests per mill heat with no test below 13.6 J (10 ft·lbs). A copy of the certified mill test reports for this steel and the Charpy V-Notch test

results shall be submitted. Sufficient information shall be furnished to demonstrate that this material is traceable to the mill heat number shown on the test report.

1320 The tapered pole shall be multi-sided or circular in shape. The pole shaft sections shall be welded together or slipfitted. The minimum diameter of the pole top shall be 190 mm (7.5 in.) and shall provide at least 25 mm (1 in.) radial clearance from all interior devices.

The exterior of the pole shall be thoroughly shotblasted or otherwise cleaned to a near white finish to remove all oily and foreign matter. The interior of the pole shall be cleaned of all mill scale and foreign matter by a pickling process or shotblasting.

Hardware shall be stainless steel in accordance with ASTM A 276, type 304 or 305, except where otherwise specified.

1330 For the slipfit design, the pole shall be made up of not more than four sections for poles up to and including 36.6 m (120 ft) in length. For the poles between 36.6 m (120 ft) and 45.7 m (150 ft), five sections will be permitted. For poles over 45.7 m (150 ft) and up to 61 m (200 ft) six sections will be permitted. The inside edge of the lower section of the slip joint shall be beveled to prevent the transition joint assembly from catching on the edge. Slip-joints shall have a minimum overlap of 1 1/2 times the diameter of the bottom of the upper section. The sections shall be pre-fitted and matchmarked at the factory.

1340 **2. Welding.** All welds shall be performed at the factory. Circumferential welds shall be backed-up welds with 100 percent penetration. Longitudinal welds shall have a minimum of 60 percent penetration except within 0.6 m (2 ft) of either side of the circumferential joint, the welds shall be backed-up and of 100 percent penetration. Base plate welds shall be of 100 percent penetration. Circumferential welds and 100 percent penetration longitudinal welds shall be 100 percent ultrasonically inspected. The 60 percent penetration longitudinal welds shall be 100 percent ultrasonically or radiographically inspected for soundness. Welding shall be performed in accordance with 711.32.

1350 **3. Handholes.** Openings for handholes shall be reinforced to maintain the design strength of the pole. The handhole shall have a weatherproof gasket made of neoprene or silicone rubber. The gasket shall be formed for a forced fit around the handhole or be attached by mechanical means. Samples of the gaskets shall be furnished for approval. The door and hinges shall be the same type steel as the poles. The hinge pins and other securing hardware shall be stainless steel and tamperproof. The door shall be fabricated to allow for a padlock, which is not included in the hardware. The hasp used for padlocking shall be fabricated from stainless steel. Provisions shall be made to bolt the door securely shut. The door shall include a bugproof and weatherproof aperture with a minimum opening of 2580 mm² (4 in²). Nylon or non-corrosive screens, or other approved methods of bugproofing shall be furnished. Two bonding plates shall be furnished which are accessible through the pole handhole for connecting the ground wires. A connection shall be furnished for an additional ground wire on the outside of the pole near the base plate.

4. Luminaire Ring Assembly. The ring shall be fabricated from ASTM A 666 Type 201 or 304 stainless steel and shall have a removable raceway cover. The ring shall be designed as an enclosed wire raceway to provide for the symmetrical mounting of luminaires having an effective projected area of 0.26 m² (2.8 ft²) and a weight of 38.5 kg (85 lbs) or actual projected area and weight, if greater. All structural connections shall be made with bolts and nuts.

1370 The luminaire ring shall be supported by three 5 mm (3/16 in.) stainless steel aircraft cables of seven strands with 19 wires each strand with a minimum breaking strength of 17,350 N (3900 lbs). The cables shall be secured to the ring, and to cable terminating devices within the poles by means of stainless steel hardware.

Positive positioning devices shall be incorporated into the ring assembly. These devices shall be designed to prevent any horizontal movement in the ring assembly. The ring assembly shall have a minimum of six nonabrasive rollers mounted on the ring interior.

1380 **5. Head Frame Assembly.** The head frame shall be made of ASTM A 666 Type 201 or 304 stainless steel. All required pulleys, rollers, or sheaves and shafts shall be constructed from non-corrosive metallic materials. No component shall be used in the lowering device in excess of its rating or in violation of the component manufacturer's recommendation. This requirement shall be applicable, but not limited to, the compatibility of the cables and sheaves. There shall be 3 supports for the suspension cables. A roller system or one compatible sheave for the power cable shall be located mid-point between two of the suspension supports. To prevent the cables from riding out of the grooves, cable guides shall be provided. The suspension cable sheaves shall have a minimum pitch diameter of 90 mm (3.5 in.) and the power cable sheave or individual rollers in a roller assembly shall have a minimum pitch diameter of 470 mm (18.5 in.) and shall be grooved to fit the power cable.

1390 All components at the top of the pole shall be protected from the weather by a dome fabricated from steel in accordance with 913.11(b)1, fiberglass, or spun aluminum.

The dome shall be secured to the head frame assembly with at least eight fasteners around the perimeter of the dome. The dome shall be reinforced at the points of attachment and it shall be fitted to the head frame assembly so that no visible distortion occurs to the dome when it is properly installed. The dome attachment shall be designed to withstand pole vibration, other pole movement, and the design windload. The fiberglass dome shall be made of material that is not subject to cracking or other deterioration because of aging.

1400 **6. Winch Assembly.** The winch cable shall be 8 mm (5/16 in.) diameter galvanized steel aircraft cable of 7 strands with 19 wires each strand with a minimum breaking strength of 9800 pounds 43,600 N (9800 lbs).

The winch shall have a drum with a minimum diameter of 100 mm (4 in.) and drum flanges with a minimum diameter of 200 mm (8 in.). The drum shall be supported at each end by a rigidly mounted permanently lubricated bearing capable of carrying the design load. The winch drum shall be designed to allow the cable to lay in even consecutive layers.

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The winch shall be driven by a self locking, worm gear reducer. The gear reducer shall be permanently lubricated and totally enclosed in a cast aluminum or cast iron housing. The winch assembly shall be powered by an external drive system.

7. External Drive System. The external drive system shall be powered by a heavy duty reversing NEMA frame motor with an electromagnetic friction breaking mechanism rated at a minimum of 8.15 J (6 ft.-lbs.) of torque per motor 745.7 W (hp). The brake shall be actuated each time the power to the motor is interrupted. The breaking mechanism shall be an integral part of the motor housing. The motor operated drive shall have a factory set torque limiter or clutch. This clutch assembly shall be calibrated to position the ring at the top of the pole and not exceed 80 percent of yield strength of the cable.

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The external drive system shall operate with the 240/480 AC volt power available at the pole or incorporate a transformer into the system. The external drive system may use either the luminaire power plug or a separate outlet with a 600 volt, 30 ampere rating. The external drive system shall be operable from a minimum distance of 7.6 m (25 ft) from the pole. The control voltage for any hand-held control equipment shall not exceed 120 volts. The hand-held control equipment shall be shock proof.

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The external drive system shall be capable of operating all high mast pole installations. Shop drawings shall be furnished in accordance with 913.11(g) and shall include the dimensions and the wiring diagram of the standard connections of the external drive system. The external drive system shall be mounted on a two wheel cart with wheels at least 300 mm (12 in.) in diameter and the weight shall be distributed so that it presents a balanced load.

8. Cable Terminator. The three luminaire ring support cables shall be attached to three stainless steel helical compression springs incorporated into the cable terminating device. These springs shall be designed to compensate for inequalities in the cable lengths and to maintain adequate tension on the support cables through pole and cable thermal expansion and contraction.

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The cable terminator shall incorporate a separate eye bolt on the bottom of the device for the attachment of a cable or chain to hold the luminaire ring in a raised position while the winch cable or winch assembly is being inspected or repaired. The cable terminating device shall be designed to prevent the device from catching on the slip joint of the structure.

9. Lightning Rod Assembly and Grounding System. The lightning rod, air terminal, shall shield the head frame assembly cover and the outer edge of the luminaires within a 45 degree electrostatic shielded cone. The grounding system shall

include bonding plates, grounding clamps, four 16 mm (5/8 in.) diameter by 3.7 m (12 ft) copperweld grounding rods, a grounding conductor with a minimum size of 28 strands of 14 gauge bare copper wire in rope lay configuration, 14 mm (9/16 in.) diameter with a weight of copper of 136 kg (375 lbs) per 306 m (1000 ft), air terminal, lightning rod and other incidental connectors. All hardware shall be stainless steel, brass, copper, copper alloy, or equally corrosion-resistant metal.

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Bonding plates, with a minimum contact surface area of 5160 mm² (8 in²), shall be installed at locations shown on the plans. The bonding plates shall be welded to the tower shaft during the time of manufacturing. The grounding conductor shall be secured to the bonding plates by a two bolt pressure plate clamp connector having a minimum of 100 mm (4 in.) of contact with the copper wire. At the point of termination the grounding conductor shall extend beyond the bonding plate a minimum of 75 mm (3 in.).

Each ground rod clamp shall have a minimum of 38 mm (1 1/2 in.) of contact between the grounding conductor and the ground rod. The grounding conductor shall be continuous between the bonding plates inside the tower shaft handhole and the grounding rod termination point.

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Bends of conductors shall form an angle of 90 degrees or more. Unsupported conductors shall have a radius of bend 200 mm (8 in.) or greater.

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10. Anchor Bolts. Anchor bolts for high mast poles shall be furnished in a pre-clustered form and shall be a hooked deformed reinforcing bar or a hooked smooth bar. The bolts shall be in accordance with ASTM A 615M (ASTM A 615) modified to a minimum yield strength of 517 MPa (75,000 lbs). The top 300 mm (12 in.) of each anchor bolt, nut, and washer shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and in accordance with the coating thickness, adherence, and quality requirements of ASTM A 153, class C.

(c) Wire and Cable. Lighting circuit cables for direct burial shall be enclosed in polyethylene conduit.

1. Polyethylene Conduit. This conduit shall be in accordance with ASTM D 3485 either medium density type II, class C or high density type III, class C smooth wall, coilable polyethylene conduit for preassembled wire and cable.

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The size of the conduit for different cable conductor sizes shall be as follows:

Cable Conductor Size	Conduit Size
3-1/C No. 4	32 mm (1 1/4 in)
3-1/C No. 2	38 mm (1 1/2 in.)
3-1/C No. 1/0	50 mm (2 in.)
3-1/C No. 3/0	50 mm (2 in.)

1500 **2. Conductors in Cable-Duct.** The cable shall consist of three separate electrically insulated conductors installed in the duct so any one conductor may be easily removed without damage to the other two. The conductors shall not be cabled or twisted together. The conductors shall be stranded copper of the AWG size specified. Conductor sizes No. 8 AWG and larger shall be stranded in accordance with ASTM B 8, class B.

1510 Each conductor shall be insulated with crosslinked polyethylene manufactured in accordance with Insulated Power Cable Engineer Association publication S66-524. Each conductor shall have the following characteristics: a 600 volt rating; UL listed; an XHHW conductor temperature rating not to exceed 90p C in dry locations; and not to exceed 75p C in wet locations.

1510 Each of the three conductors shall be imprinted at regular intervals with the following description: Type XHHW; 600 volt; UL; the conductors' AWG size and metal or alloy; the manufacturer's name, trademark, or other distinctive marking by which the product can be readily identified.

1520 Identification coding of the conductors shall be accomplished by complete color coding or by ribbing of the insulation. Color coding of the insulation shall be homogeneous throughout the entire depth and length of the jacket. The colors shall include one black, one white, and one red. Ribbing shall consist of one non-ribbed conductor, one single ribbed conductor, and one double ribbed conductor. The same method of conductor identification coding shall be used throughout the project.

1530 **3. Lighting Standard Circuit Wiring.** This wiring shall consist of two 1/C No.10 AWG, 600 volt, THWH or MTW insulation, stranded, copper wire.

1530 **4. Sign and Underpass Wiring.** The wiring from the switch box to the last luminaire shall be 3/C copper stranded No. 10 AWG conductors and shall have imprinted at regular intervals along the length of the insulation jacket the following designation: No. 10 AWG, type MTW or THHN or THWN or Gasoline and Oil Resistant II or AWM, 600 volt, UL. The conductor classifications shall be UL listed and have the following minimum temperature ratings: MTW 90pC; THHN 90pC; THWN 75pC; and AWM 105pC. It shall be installed in 19 mm (3/4 in.) conduit between the breaker box and luminaires.

1540 **5. Aerial Cable.** This cable shall be triplex secondary distribution cable consisting of two insulated conductors and a steel reinforced bare copper messenger neutral. The insulated conductor shall be No. 6 AWG stranded copper with 600 volt, XHHW-XLP type insulation.

1540 **6. High Mast Tower Luminaire Ring Conductors.** The wiring from the terminal box on the ring through the last luminaire shall be in accordance with 913.11(c)4.

1540 **7. Power Cable-High Mast Poles.** The power cable shall be a 4/C No. 10 AWG copper insulated electrical cable type "SO" modified for a repetitive reeling

operation. It shall be in accordance with ASTM B 3, ASTM B 173, and IPCEA S-19-83. Conductor insulation shall be in accordance with ASTM D 169 and IPCEA S-19-81, Paragraph 3.12. The sheath or jacket shall meet or exceed IPCEA S-19-81, Paragraph 7.6.20.1.1. Conductors shall be color coded.

The power cable shall have a heavy-duty 600 volt, AC 30 amp rated electrical plug capable of disconnection in a safe manner under load conditions. The electrical plug shall be moisture resistant and waterproof at both transition points.

8. Electrical Connectors. Connectors shall be a compression type of the proper size with only one conductor per groove in the fitting. They shall be designed specifically for use on aluminum and copper conductors, prefilled with an oxide inhibitor and installed with a hydraulic tool according to the manufacturer's specifications. After installation, the connectors shall be fully insulated and weatherproofed. The connectors installed in underground handhole shall be taped and then waterproofed as shown on the plans.

(d) Luminaires.

1. General Requirements. Lamps supplied for luminaires shall be electrically compatible with the luminaires. Luminaires shall include the lamp ballast. The ballast shall be integrally built in and of the constant wattage regulator type of sufficient size to operate the designated lamp at the required voltage. The ballast shall provide satisfactory lamp performance to -7 μ C (20 μ F) with an input voltage variation of ± 10 percent of the rated operating voltage specified.

Luminaires shall include vandal shields when installed on an underpass or signs on bridge brackets and when otherwise specified. The vandal shield shall be made of a tough durable plastic, such as Lexan, mounted in a rugged galvanized steel or aluminum frame, and shall withstand severe impact without being damaged or allowing the refractor to be damaged. It shall be fastened securely to the luminaire so it can not be removed from the outside and shall not interfere with the light distribution pattern. It shall protect the face of the refractor and if ventilation is necessary, the ventilating apertures shall be arranged so that they do not admit a probe of a diameter greater than 6 mm (1/4 in.).

2. Roadway Lighting Luminaires. Roadway lighting luminaires shall have a precision-cast aluminum housing and refractor holder with weatherproof finish. They shall have a strong, easily operated, positive latch on the street side of the refractor holder and a hinge with a safety catch that prevents accidental unhinging on the house side of the refractor holder. They shall include a slipfitter capable of adapting to a 50 mm (2 in.) mounting bracket; an easily detachable highly specular aluminum reflector; and an easily adjustable socket in both horizontal and vertical directions capable of producing lighting patterns to meet all the requirements of the American Standard Practice for Roadway Lighting as sponsored by the Illumination Engineering Society and as shown on the plans. They shall have a high impact, heat-resistant, glass, prismatic refractor; and include gasketing that will completely seal out dust, moisture, and insects from the interior of the optical assembly and retard the formation of an undesirable film from gaseous vapors on the interior of the optical assembly.

3. Sign Luminaires. Luminaires shall be 250W mercury vapor unless otherwise specified. Sign luminaires shall have the same requirements as roadway luminaires plus a shield that blocks the view of the refractor from an approaching motorist. This shall be accomplished by the design of the housing or by a shield fabricated from sheet aluminum, approximately 1.3 mm (0.05 in.) thick, and of sufficient size to be fastened onto the horizontal edge of the refractor holder with self tapping screws and placed between the refractor and approaching traffic.

Aluminum and steel structural members for luminaire supports shall include aluminum conduit, conduit clamps, fittings, and stainless steel screws.

4. Underpass Luminaires. Underpass luminaires shall have the same requirements as roadway luminaires except they shall have vandal shields and the ballast shall meet the same requirements except it may be mounted separately near the luminaire as shown on the plans.

5. High Mast Luminaires. The luminaires shall be in accordance with the American Standard Practice for Roadway Lighting by the Illumination Engineering Society and shall produce lighting patterns as shown on the plans. The lamp in the high mast luminaire shall be supported at both ends with mechanical spring grips or other means to hold the lamp secure against vibration. The socket shall be mogul sized and porcelain enclosed. The luminaire housing shall be an enclosed aluminum unit with a reflector and borsilicate glass refractor. It shall include gasketing that completely seal out dust, moisture, and insects from the interior of the optical assembly and retard the formation of an undesirable film from gaseous vapors on the optical assembly.

(e) Circuit Breakers and Enclosure. All circuit breaker enclosures shall be NEMA 4/5.

1. Circuit Breakers for Type II Service Point. The cabinet and hardware shall be weatherproof and rain tight. The enclosure shall have provisions for pad locking. The fastener and mounting hardware shall be plated brass, stainless steel, or aluminum. The enclosure shall be made of 14 gauge aluminum or 1.5 mm (14 or 16 gage) stainless steel. The circuit breaker operating handles for manual tripping shall be concealed inside the enclosure. Computation of branch circuits shall be based on the National Electrical Code Standard Limitation of loading breakers to 80 percent of their rated current. Additional details shall be as shown on the plans.

2. Circuit Breakers for Sign and Underpass Circuits. Sign and underpass circuit protection shall be provided by two single pole, 240 volt AC, 120 volt for 120/240 volt service, circuit breakers with ampere rating of 200 percent of the normal load. The circuit breakers shall have provisions for padlocking externally. The circuit breaker operating handles for manual tripping shall be concealed inside the enclosure. The enclosure shall be made of aluminum or stainless steel. Additional details shall be as shown on the plans.

3. Circuit Breakers for High Mast Poles. The enclosure shall be furnished with two single pole, 30 ampere, 480 volt AC circuit breakers with a minimum symmetrical RMS interrupting capacity of 14,000 amperes. The breakers shall be accessible through the

pole handhole. The circuit breaker operating handles for manual tripping shall be external to the enclosure. The enclosure shall be made of aluminum or stainless steel. Additional details shall be as shown on the plans.

4. E-Series magnetic circuit breakers shall have the following features:

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- a. Capable of 10,000 on-off operations.
- b. Interrupting capacity of 7,500 amperes.
- c. Temperature stable so as not to be adversely affected by temperature changes over their operating environment of -40°C (-40°F) to 85°C (185°F).
- d. Lug range 1/0 - 14 copper and 1/0 - 12 aluminum.

1660

- e. Trip on overload, even when handle is forcibly held in the ON position.

(f) Multiple Relay Switches with Photocell Receptacles. Multiple relay switches with photocell receptacles shall have a two pole relay for connection to a 120/240 or 240/480 volt, 3 wire, single phase, 60 hz power supply. The relay switch components shall match the service voltage being supplied. The unit shall contain two single pole circuit breakers with a minimum rated capacity to withstand 100 percent of the rated ampere load. The circuit breakers shall trip at not less than 125 percent of the rated load capacity. Control circuit arresters for lightning protection and a manual control selector switch shall be included within the unit. The enclosure shall be a cast aluminum weatherproof case, with a hinged cover, having provisions for padlocking and a hanger for pole or wall mounting.

(g) Shop Drawings. Six sets of shop drawings shall be submitted for lighting standard assemblies, luminaires, service points, circuit breaker enclosures, external drive assemblies, and multiple relay switches. A copy of the transmittal shall be given to the Engineer. These items shall not be ordered or installed until shop drawings have been approved.

These drawings will be reviewed for design features only. The Contractor shall be responsible for dimensions, accuracy, and fit of work. The drawings for conventional light standards shall show the shaft outside diameter, height, wall thickness, the arm length rise, size, handhole details, grinding details, materials used, and complete anchor bolt details including bolt circle-projection and hardware. When a breakaway base is required, details shall be shown. Service point shop drawings shall show the arrangement and brand name of each component.

When requested, sufficient design data shall be furnished with the drawings to verify the conventional light standards meet wind load, deflection, vibration, and breakaway requirements. All of the above shall be based upon the lighting standards as shown on the plans. After approval, the Engineer shall be advised of where changes to the Installation Summary Sheets must be made because of existing roadside conditions. Where necessary, additional light standard drawings shall be submitted for approval.

Unless calculations are on file with the Department, the following design calculations and data shall be submitted for approval prior to the fabrication of any parts of the high mast pole.

1. General dimensions of all component parts.
2. The maximum moments, the section modulus required, and the section modulus furnished at the base of the pole, at all splices, at the connection of the ring and at least every 6.1 m (20 ft).
3. Computation of stresses in base plate, connection attachment, and anchor bolts.
4. Maximum deflection at the top of the structure under the specified loading.
5. The dimensions and wiring diagrams of the external drive system connection to the pole in accordance with in 912.11(b)7.

(h) Materials Certification. Unless otherwise specified, materials furnished under this specification require a type C certification in accordance with 916.

913.12 Construction Warning Lights.

1720 **(a) Types of Warning Lights.**

1. Type A. Type A shall be a low intensity flashing barricade warning light.

2. Type B. Type B shall be a high intensity flashing barricade warning light.

3. Type C. Type C shall be a steady burn barricade warning light.

1730 **(b) General Requirements.** The light shall be self-illuminated by means of an electric lamp behind the lens. Types A and C also shall be externally illuminated by reflex-reflective elements built into the lens to enable it to be seen by reflex-reflection of the light from the headlights of oncoming traffic.

When the unit is to be operated by batteries, the batteries shall be entirely enclosed in a case. The case shall be secured by a locking device which can be opened by a special wrench or tool.

1740 When the unit is to be operated by a 120 volt, 60 cycle power supply, the unit shall be supplied with a separate ground wire and be protected with suitable fuses. The connections and equipment used shall be in accordance with the pertinent current standards of the Institute of Electrical and Electronic Engineers, the ASTM, and the National Board of fire Underwriters. In those areas where there are pertinent local ordinances and requirements, the wiring, materials, and installation procedures shall be in accordance with them.

(c) Flash Requirements.

1. Flash Rate. The light from types A and B shall have a flash rate of 65 ± 10 pulsations per minute from -29°C (-20°F) to $+66^{\circ}\text{C}$ (150°F) regardless of power source.

1750 **2. On-Time.**

a. Definition. On-time is defined as the period of the flash when instantaneous intensity is equal to or greater than the effective intensity as specified in 913.12(d)1.

b. Type A. The light shall have an on-time of no less than 10 percent of the flash cycle.

1760 **c. Type B.** The light shall have an on-time of no less than 8 percent of the flash cycle.

(d) Optical Requirements.

1. Effective Intensity. The light beam projected upon a surface perpendicular to the axis of the light beam shall produce a lighted area within the solid angle bounded by the two vertical planes 9 degrees from the vertical plane through the axis of the optical system and two planes 5 degrees above and below the horizontal plane through the optical axis of the system.

For type A, the effective intensity shall not drop below 4.0 candles within the area specified herein during the first 336 hours of continuous flashing.

For type B, the effective intensity shall not drop below 35 candles within the area specified herein during the first 168 hours of continuous flashing.

For type C, the beam candle power shall not drop below 2.0 candles within the area specified herein during the first 168 hours of continuous burning.

2. Lens Illumination. The illuminated lens shall be uniformly bright in appearance over its entire illuminated surface when viewed from any point within the angle defined in 912.12(d)1.

3. Reflex-Reflective Performance. For types A and C the specific intensity of the lens when acting as a reflex-reflector at an observation angle of 0.2 of a degree shall be no less than the following:

Entrance Angle (degrees)	Specific Intensity Candela per lux (Candle per Footcandle)
0	1.67 (18)
10	1.40 (14)
20	0.65 (7)

4. Testing Procedure. The effective intensity of types A and B lights shall be calculated using the Guide for Calculating the Effective Intensity of flashing Signal Lights as approved by the Illuminating Engineering Society, June, 1961. The intensity of the type C light shall be tested in accordance with SAE Standard J 575d, Lighting Equipment and Photometric Tests. Reflex-reflection shall be tested in accordance with SAE Standard J 594d.

(e) Lens Requirements.

1. Size of Lens. The lens shall be no less than 175 mm (7 in.) in diameter including for types A and C a reflex-reflector ring of 13 mm (1/2 in.) minimum width around the periphery.

2. Number of Lenses. Unless otherwise directed, types A, B, and C shall have uni-directional lenses.

3. Lens Chromaticity. If the light uses an incandescent lamp, the chromaticity of the lens color shall be defined by the tri-stimulus coordinates of the Commission International d'Eclairage Standards. When tested with illuminants from 2856 K to 2366 K, the lens color shall fall within the area of the chromaticity diagram in accordance with the 1931 Commission International d'Eclairage Standard Observer as defined by the following coordinates:

X	Y	Z
0.543	0.452	0.005
0.548	0.452	0.000
0.584	0.411	0.005
0.589	0.411	0.000

If the light uses other than an incandescent lamp, the light output shall be in the same range as the light obtained with the incandescent lamp and the specific lens.

4. Lens Luminous Transmittance. The minimum relative luminous transmittance of the lens with illuminant at 2856 K shall be 0.440.

5. Lens Material. The lens shall be plastic of one piece construction. The lens material shall meet the test requirements in accordance with SAE J 576b, except that the exposure time and condition, paragraph 3.4.3, for the purposes of this standard shall be one year.

(f) Head and Housing.

1. Swivel Head. If swivel capabilities as described herein are not incorporated in the device used to mount a type A or C light on a barricade or sign, the head shall be mounted on the housing in a manner permitting it to be swiveled through a minimum 90 degrees arc in a horizontal plane. If swiveling is accomplished by rotation of the head, construction shall be such that the head rotation will not damage the wiring.

2. Housing. Housing shall be the case containing the batteries and circuitry. The housing shall be constructed of No. 1.2 mm (18 gage) steel or other approved material.

3. Weatherproofing. The case shall be so constructed and closed as to exclude moisture that would affect the specified operation of the light. The case shall have a weep hole to allow the escape of moisture from condensation.

(g) **Photoelectric Controls.** Photoelectric controls, if provided on types A or C lights, shall keep the light operating whenever the ambient light falls below 215 lux (20 footcandles).

(h) **Basis For Use.** A type C certification in accordance with 916 shall be provided for construction warning lights, except it shall be prepared by the Contractor, and not a manufacturer.

1860

913.13 Flashing Arrow Sign. The flashing arrow sign shall be an all weather, self-contained flashing sign designed to display the required flashing messages continuously for a minimum of 24 hours, without servicing. A reserve storage battery shall be provided to automatically operate the flashing arrow sign for a minimum period of 8 hours if there is a power failure of the primary source.

1870

The flashing arrow sign shall have a control unit which incorporates a photo-controlled transfer relay for automatic lamp intensity settings. The highest photo-controlled setting shall be full intensity for daylight operation. The lowest photo-control setting shall be for night-time operation and shall be 50 percent of full intensity when the ambient light level drops below 54 lux (5 footcandles). A minimum of two interim photocontrolled settings shall automatically increase or decrease the lamp intensity in direct proportion to the ambient light level.

The flashing arrow sign shall have a manual control unit for adjusting lamp intensity when automatic operation becomes unsatisfactory. The manual control shall be fully adjustable between the minimum limit of 30 percent of full lamp voltage and maximum limit of full lamp voltage.

FLASHING ARROW SIGN GENERAL SPECIFICATIONS

	TYPE A	TYPE B
Minimum Board Size	0.6 m (2 ft) high x 1.2 m (4 ft) wide**	See Note Below
Minimum No. of Lamps Flashing Arrow Flashing Double Arrow Sequential Chevron (3 Heads Minimum)	125 mm (5 in.) head 125 mm (5 in.) shaft* 125 mm (5 in.) head 100 mm (4 in.) shaft* 125 mm (5 in.) head	
Lamp Type	Sealed Beam - 12.8 volts, not to exceed 3 amps. Average rated life - 300 hours, or greater. Candlepower - 1000 minimum, 9700 maximum	
Lens Color	Amber	
Board Color	Flat Black	
Flashing Rate	30-50 F.P.M. (50% on time)	
Message (Left or Right)	Flashing Arrow, Flashing Double Arrow, or Sequential Chevron	
Minimum mounting height (to bottom of board)		
Where Permitted	Where normal speed limit is less than 65 km/h (40 mph)	
Required Minimum Visibility	0.8 km (0.5 mi.)	

1890

1900

- * When flashing a single or double arrow(s), the lamp(s) nearest the arrow points will not be illuminated.
- ** Either rectangular or arrow shaped black background sign will be permitted.
- Note: General specifications for a type B flashing arrow sign are shown in the Federal MUTCD. However, the Indiana MUTCD and this specification do not show the general specifications for a type B flashing arrow sign.

FLASHING ARROW SIGN GENERAL SPECIFICATIONS

1910

	TYPE C
Minimum Board Size	1.2 m (4 ft) high x 2.4 m (8 ft) wide
Minimum No. of Lamps Flashing Arrow Flashing Double Arrow Sequential Chevron (3 Heads Minimum)	125 mm (5 in.) head 125 mm (5 in.) shaft** 125 mm (5 in.) head 125 mm (5 in.) shaft** 125 mm (5 in.) head
Lamp Type	Sealed Beam Par 46-12.8 volts, not to exceed 3 amperes. Average rated life - 300 hours, or greater. Candlepower - 8800 minimum, 9700 maximum
Lens Color	Amber
Board Color	Flat Black
Flashing Rate	30-50 F.P.M. (50% on time)
Message (Left or Right)	Flashing Arrow, Flashing Double Arrow
Minimum mounting height (to bottom of board)	2.1 m (7 ft)
Where Permitted	All rural & urban locations
Required Minimum Visibility	1.6 km (1 mi.)

1920

- * When flashing a single or double arrow(s), the lamp(s) nearest the arrow points will not be illuminated.
- ** Either rectangular or arrow shaped black background sign will be permitted.
- Note: General specifications for a type B flashing arrow sign are shown in the Federal MUTCD. However, the Indiana MUTCD and this specification do not show the general specifications for a type B flashing arrow sign.

1930

913.14 Pavement Marking Material.

(a) Traffic Paint. Traffic paint shall be in accordance with 909.05.

(b) Durable Marking Material. Durable marking material shall be thermoplastic, preformed plastic, or 100 percent solids epoxy.

1940

1. Thermoplastic. This material shall be supplied in the solid form and heated to achieve a plastic state suitable for application. In the plastic state, the material shall not give off fumes which are toxic or otherwise injurious to persons or property. The material shall not breakdown, deteriorate, scorch or discolor if held at the

application temperature of 204° C (400° F) to 232° C (450° F) for a period of 4 hours or by reason of reheating to the application temperature four additional times. The temperature versus viscosity characteristics of the material shall remain constant through the four reheatings and shall be constant from batch to batch. The color shall be stable through the four reheatings and shall be the same from batch to batch.

1950

The thermoplastic material shall be homogeneous and free from dirt, foreign objects, or ingredients which will cause bleeding, staining or discoloration. The thermoplastic material shall not be adversely affected by contact with deicing chemicals, bituminous paving materials, or drippings from vehicles.

The marking shall have a uniform cross section. Pigment shall be evenly dispersed throughout the material. The density and character of the material shall be uniform throughout its thickness. The marking shall maintain its original dimensions and placement.

1960

The thermoplastic material shall remain intact under normal traffic conditions at temperatures below 49° C (120° F). The material shall not separate from the pavement in freezing weather. Cold ductility of the material shall be such as to permit normal movement with the road surface without chipping or cracking.

The color of the white plastic film shall be determined by a standard color difference meter, such as the Gardner Color Difference Meter manufactured by Gardner Laboratories, Inc., Bethesda, Maryland. The plastic film shall not show deviations from a magnesium oxide standard greater than the following:

1970

SCALE	DEFINITION	MAGNESIUM OXIDE	SAMPLE
Rd	Reflectance	200	70 Minimum
a	Redness-Greenness	0	-5 to +5
b	Yellowness-Blueness	0	-10 to +10

The color of the yellow plastic film shall visually match color No. 33538 of Federal Standard 595a. The pigment shall include medium chrome yellow.

1980

a. Material Requirements. The filler to be incorporated with the resins shall be white calcium carbonate meeting requirements of ASTM D 1199, type GC, grade II or III. The binder shall consist of a mixture of non-drying synthetic resins at least one of which is solid at room temperature. The total binder content of the thermoplastic compound shall be from 18 percent minimum to 35 percent maximum by weight. The white thermoplastic shall have a pigment containing a minimum 10 percent titanium dioxide. The glass beads shall be in accordance with 912.09.

(1) Reflectorization. During manufacture, reflectorizing beads shall be mixed into the compound from 20 percent minimum to 35 percent maximum by weight of the material.

1990

(2) Set Time. The set time to bear traffic shall have a lower limit of 2 minutes maximum at 10 °C (50 °F) surface temperature and an upper limit of 15 minutes at 32 °C (90 °F) surface temperature when the film is applied at the maximum permitted thickness.

(3) Water Absorption. The retained water shall not exceed 0.5 percent by weight when tested in accordance with ASTM D 570, procedure A.

2000

(4) Softening Point. Material shall have a softening point of 88 °C (190 °F) minimum when tested in accordance with ASTM E 28.

(5) Specific Gravity. Specific gravity of the compound at 25 °C (77 °F) shall be from 1.9 to 2.5.

2010

(6) Impact Resistance. The impact resistance shall be a 1.7 J (15 in·lbs) minimum at 25 °C (77 °F) after the material has been heated for 4 hours at 204.5 °C (400 °F). The material shall be cast into bars of 25 mm (1 in.) cross sectional area and 75 mm (3 in.) long and placed with 25 mm (1 in.) extending above the vise as a cantilever beam, Izod type tester using the 2.8 J (25 in·lbs) scale in accordance with ASTM D 256.

(7) Low Temperature Stress Resistance. Samples shall not crack nor fail to adhere to substrate when tested. A line sample which is a minimum of 0.021 m² (32 in²) in area shall be applied to an asphalt paving block in a manner equivalent to an actual road installation. The block shall be immersed in cold water for one hour, then immediately placed in a freezer chest or other insulated cold compartment maintained at -7 °C (20 °F) for 24 hours. The block shall be removed from the cold compartment and allowed to come to normal room temperature. The line sample shall show no cracking or flaking off the block when examined following the exposure cycle.

2020

(8) Bond Strength. Two concrete blocks 50 mm by 90 mm by 178 mm (2 in. by 3 in. by 7 in.) shall be bonded together on the 76 mm by 178 mm (3 in. by 7 in.) faces with a 1.6 mm (1/16 in.) to 3.2 mm (1/8 in.) layer of the thermoplastic marking material and tested in accordance with ASTM C 321, the bond strength shall not be less than 150 pounds per square inch (1.034 MPa).

(9) Hardness. The material shall be conditioned by heating for 4 hours at 204 °C (400 °F). The hardness shall be measured at the designated temperatures as the material cools and shall comply with the indicated minimum reading. The hardness shall be measured after 15 seconds of penetration using the Shore Durometer type A in accordance with ASTM D 2240.

2030

TEMPERATURE	READING
46° C (115° F)	65
25° C (77° F)	95
2.5° C (40° F)	95

2040 **b. Packaging.** The thermoplastic material shall be delivered in unit containers. Each unit container shall be clearly marked to indicate the color of the material, the process batch number or similar manufacturer's identification, the manufacturer's name and location of plant, and the date of manufacture.

c. Basis for Use. A type C certification in accordance with 916 shall be furnished for the thermoplastic material.

2050 **2. Preformed Plastic.** This material shall consist of a homogeneous preformed plastic film with a minimum thickness of 1.5 mm (60 mils) and a width as specified. The preformed plastic material shall have a precoated adhesive and an easily removable backing which shall protect the adhesive in storage and facilitate rapid application. The adhesive shall allow the preformed plastic material to be repositioned on the pavement surface to which it is applied before permanently fixing it in its final position with downward pressure.

The plastic material shall be capable of being affixed to either bituminous concrete pavement or cement concrete pavement by means of the precoated adhesive and, following the initial application of pressure, shall mold itself to pavement contours, breaks, and faults by traffic action at normal pavement temperatures.

2060 The color of the white plastic film shall be determined by a standard color difference meter, such as the Gardner Color Difference Meter manufactured by Gardner Laboratories, Inc., Bethesda, Maryland. The plastic film shall not show deviations from a magnesium oxide standard greater than the following:

SCALES	DEFINITION	MAGNESIUM OXIDE	SAMPLE
Rd	Reflectance	100	70 Minimum
a	Redness-Greenness	0	-5 to +5
b	Yellowness-Blueness	0	-10 to +10

2070 The color of the yellow plastic film shall be visually match color No. 33538 of Federal Standard 595a. The pigment shall include medium chrome yellow.

a. Material Requirements. The material shall be composed of plasticizers, pigments and glass beads. The pigment shall contain 20 percent minimum titanium dioxide for white plastic material. During manufacture, glass beads shall be mixed into the compound at a minimum of 15 percent and a maximum of 20 percent by weight. A layer of glass beads shall be bonded to the top surface.

2080 **(1) Tensile Strength.** The specimens for this test shall be Type I prepared in accordance with ASTM D 638M (ASTM D 638). A sample 150 mm by 25 mm (6 in. by 1 in.) shall be tested at a temperature between 21 °C (70 °F) and 27° C (80° C) using a jaw speed of 6.4 mm (0.25 in.) per minute. 25 mm (1 in.) squares of carborundum extra coarse emery cloth or equivalent may be applied to each end of the

test sample to prevent the plastic adhesive from adhering to the test equipment. The break resistance shall be based on an average of at least three samples. The elongation of the film at rupture shall be 15 percent minimum and 50 percent maximum. The minimum tensile strength shall be 275.8 MPa (40 psi).

2090

(2) Adhesive Stability Test. A 75 mm by 150 mm (3 in. by 6 in.) sample of plastic material shall be applied to a 75 mm by 150 mm (3 in. by 6 in.) piece of carborundum extra coarse emery cloth or equivalent, so that a 75 mm by 75 mm (3 in. by 3 in.) overlap occurs. The specimen shall withstand a static load of 17.8 N (4 lbs) for a period of 30 minutes, in accordance with ASTM D 816, method B. The slippage between the plastic sample and the emery cloth shall not exceed 25 mm (1 in.). The test shall be conducted at a temperature between 21 °C (70 °F) and 27 °C (80 °F).

2100

(3) Adhesive Shear Strength. Specimens shall be tested in accordance with the method described in ASTM D 638M (ASTM D 638) as modified to test the adhesive shear strength. Plastic samples cut to dimensions of 25 mm by 150 mm (1 in. by 6 in.) shall have applied to the adhesive face a 25 mm by 75 mm (1 in. by 3 in.) piece of carborundum extra coarse emery cloth, or its equivalent, so that there is a 645 mm² (1 in²) overlap at one end of the plastic specimens. A pressure of 344.7 kPa (50 psi) shall be applied over this area for a period of 30 seconds. The load shall be applied by gripping each end of the test piece in a suitable tensile test machine such as a Dillon or Scott Tester. The average of the load required to break the adhesive bond shall be 4.5 kg (10 lbs) minimum. The speed of testing shall be conducted at a temperature between 21 °C (70 °F) and 27 °C (80 °F) and at a speed of 50 mm (2 in.) per minute.

2110

(4) Bend Test. At a temperature of 27 °C (80 °F) the property of the plastic material shall be such that a piece 75 mm by 150 mm (3 in. by 6 in.) with the side covered by backing paper placed against a 25 mm (1 in.) mandrel may be bent over the mandrel until the end faces are parallel and 25 mm (1 in.) apart. Visual inspection shall show no apparent fracture lines in the uppermost surface.

b. Packaging. Each package shall be marked to indicate the color of the material, specific symbol or word message, the batch number, the manufacturers name, address, and the date of manufacture.

2120

c. Basis For Use. A type C certification in accordance with 916 shall be furnished for the preformed plastic material.

3. 100 Percent Solids Epoxy. This material shall be a two component material. Component A shall consist of pigment and epoxy resins formulated as set out by the manufacturer. The mixing ratio for the two components of the material shall be as recommended by the material manufacturer. This ratio shall not vary more than $\pm 2 \frac{1}{2}$ percent during the mixing operation or the application procedures of these materials.

2130

Component A shall have the following properties:

Property	Minimum % By Weight
Pigment	
White, TiO ₂ , conforming to ASTM D 476, Type II	22
Yellow, Medium chrome yellow conforming to ASTM D 211, Type III	25
Epoxy Resins	
White	77
Yellow	70

The pigment composition shall consist of either titanium dioxide or medium chrome yellow. The epoxide value shall be tested in accordance with ASTM D 1652 and shall be 300 to 375 for both white and yellow component A, pigment free basis.

2140

Component B shall be a curing agent and shall have the amine number tested in accordance with ASTM D 2071. The amine number shall be 300 to 450.

The system, component A plus component B, shall contain no volatile solvents.

a. Material Requirements.

(1) Glass Beads. The glass beads shall be in accordance with 913.09.

2150

(2) Abrasion Resistance. The material shall be abraded with 1000 cycles using a 1000 gram load on CS-17 wheels in accordance with ASTM D 4060. The average loss in weight shall not exceed 82 milligrams. The tests shall be a run on cured samples which have been applied at a film thickness of $375 \mu\text{m} \pm 38 \mu\text{m}$ (15 mils $\pm 1 \frac{1}{2}$ mils) to code S-16 stainless steel plates. The films shall be allowed to cure at a temperature between 21 $^{\circ}\text{C}$ (70 $^{\circ}\text{F}$) to 27 $^{\circ}\text{C}$ (80 $^{\circ}\text{F}$) for 72 hours prior to performing the indicated test. The test panel shall be unbeaded.

2160

(3) Hardness. The epoxy materials shall be tested in accordance with ASTM D 2240 and have a Shore D hardness of between 75 to 100. Films shall be cast on a suitable substrate at $375 \mu\text{m} \pm 38 \mu\text{m}$ (15 mils $\pm 1 \frac{1}{2}$ mils) in thickness and allowed to cure at a temperature between 21 $^{\circ}\text{C}$ (70 $^{\circ}\text{F}$) to 27 $^{\circ}\text{C}$ (80 $^{\circ}\text{F}$) for 72 hours prior to performing the indicated test.

2170

(4) Tensile Strength. The material shall be tested in accordance with ASTM D 638M (ASTM D 638). The tensile strength shall not be less than 41.4 MPa (6000 psi). The type IV specimens shall be cast in a suitable mold not more than 6.4 mm (1/4 in.) thick. The samples shall be allowed to cure at a temperature between 21 $^{\circ}\text{C}$ (70 $^{\circ}\text{F}$) to 27 $^{\circ}\text{C}$ (80 $^{\circ}\text{F}$) for 72 hours prior to performing the indicated tests. The rate of pull shall be 6.4 mm (1/4 in.) per minute.

(5) Compressive Strength. The material shall be tested in accordance with ASTM D 695M (ASTM D 695), except as modified herein. The cured epoxy material shall have a minimum compressive strength of 82.7 MPa (12,000 psi). The cast sample shall be conditioned at a temperature between 21 °C (70 °F) to 27 °C (80 °F) for 72 hours before performing the indicated tests. The maximum rate of compression of these samples shall be 6.4 mm (1/4 in.) per minute. The sample size shall be 13 mm (1/2 in.) high by 13 mm (1/2 in.) in diameter.

(6) Weather Resistance. The mixed epoxy compound, both white and yellow, shall be applied to 75 mm by 150 mm (3 in. by 6 in.) aluminum panels at a thickness of $375\ \mu\text{m} \pm 25\ \mu\text{m}$ (15 mils \pm 1 mils) with no glass beads and cured at a temperature between 21 °C (70 °F) to 27 °C (80 °F) for 72 hours. The cured samples shall be exposed in an Environment Testing Chamber as described in ASTM G 53. The test shall be conducted for 80 hours at 50 °C (122 °F) in alternating cycles of 4 hours condensation and 4 hours ultraviolet light.

SPECIMEN	REQUIREMENTS
White Material	ASTM E 97, directional reflectance a minimum 80% after exposure.
Yellow Material	Initially conform to V+ to C+ limits when visually compared with the highway yellow color tolerance chart, PR#1 of June 1965. The color of exposed material shall be within V+, C+, and H+ limits when visually compared.

(7) Laboratory Drying Time. The epoxy pavement marking material shall be mixed in the proper ratio and applied at $375\ \mu\text{m} \pm 38\ \mu\text{m}$ (15 mils \pm 1 1/2 mils) wet film thickness at 24 °C \pm 1 °C (75 °F \pm 2 °F) with the proper application of glass beads. It shall exhibit a maximum no tracking time of 10 minutes when tested in accordance with ASTM D 711.

(8) Viscosity. Formulations of each component shall be such that the viscosity of both components shall coincide within 10 percent at a recommended spray temperature. Component B shall be formulated so as to have a steady and constant viscosity at temperatures recommended for spray application.

b. Materials Preparation. Before mixing, the individual components shall be heated to the following temperatures:

Component	Temperature °C (°F)
A	32 to 38 (90 to 100)
B	21 to 38 (70 to 100)

Each component shall be stirred thoroughly prior to mixing. After mixing, the application temperature for the combined materials at the gun tip shall be between 32 °C (90 °F) and 38 °C (100 °F).

2220 **c. Packaging and Storage.** The epoxy material shall be shipped to the job site in white epoxy lined drums which are plainly marked with the manufacturer's name and address, component identification A or B, the color of the material, date of manufacture and batch number. Storage shall be at temperatures between 1.7 °C (35 °F) and 38 °C (100 °F).

The reflective glass beads shall be shipped in 22.7 kg (50 lb) moisture resistant bags. Each bag shall be marked in accordance with 913.09.

2230 **d. Basis For Use.** Pavement marking material, except glass beads, furnished under this specification shall be covered by the type A certification in accordance with 916. A type A certification shall be furnished for each batch supplied. The material manufacturer shall perform all tests included elsewhere herein on each batch and shall provide these test results as part of the type A certification.

(c) Temporary Pavement Marking Tape. Temporary pavement marking tape shall be furnished in two colors and two types. It shall consist of a white or yellow reflecting film on a conformable backing which is a minimum of 100 mm (4 in.) wide, and is designed for marking either asphalt or concrete pavements.

2240 The white or yellow reflective film on the tape shall be in accordance with highway colors. The tape shall have an average thickness, as determined by 5 micrometer readings, of no less than 0.50 mm (20 mils). The type I reflective film shall have glass beads uniformly distributed throughout the reflective film. Type I and type II reflective film shall have a reflective layer of glass beads bonded to the surface.

2250 The tape shall be supplied in rolls ready for application and have a precoated, pressure sensitive adhesive on the backing which shall not require activation procedures. There shall be no more than three splices per 46 m (50 yds) of length. It shall be shipped in standard commercial containers so constructed as to ensure acceptance by the carrier and prevent damage during shipment and storage. It shall be capable of being stored at temperatures up to 38 °C (100 °F) for periods of one year without deterioration.

When the tape is applied in accordance with the manufacturer's recommended procedures, it shall be weather and traffic resistant and show no appreciable fading, lifting, or shrinkage during the useful life of the line. The material shall be of good appearance, free from cracks, and edges shall be true, straight, and unbroken. The material shall be capable of performing satisfactory for a minimum of one year.

2260 Type I tape shall be prequalified for use and each manufacturer shall provide the Procurement and Distribution Division with samples for field evaluation. The Department will maintain a list of approved type I tape.

Type I and type II tape furnished under this specification shall be covered by a type C certification in accordance with 916.

The minimum reflective intensity values expressed as 0.12 Candela/m²/lux (candlepower/ft²/foot candle) when tested in accordance with ASTM D 4061 shall be in accordance with the following table:

Specific Luminance using Entrance Angle 86 Degree

Observation Angle	White		Yellow	
	0.2p	0.5p	0.2p	0.5p
Specific Luminance, Type 1	1770	1270	1310	820
Specific Luminance, Type 2	1000	760	820	510

(d) Raised Pavement Marker. The raised pavement marker shall be either snowplowable, which is inset into the pavement, or temporary, which is affixed with adhesive to the pavement surface.

1. Snowplowable Raised Pavement Marker. Snowplowable raised pavement marker shall consist of a durable base to which is attached a replaceable prismatic retro-reflector for reflecting light longitudinally along the pavement from a single or from opposite directions. Both ends of the casting shall be shaped to deflect a snowplow blade upward.

a. Prismatic Reflector. The dimensions of the reflector face shall be nominal width of 100 mm (4 in.) and a minimum vertical height of 12 mm (0.460 in.) with a slope of 30 degrees from the horizontal to the face. Minimum reflecting surface area shall be 1045 mm² (1.62 in²). The reflectors shall consist of an acrylic plastic shell filled with tightly adherent potting compound. The shell shall contain one or two prismatic faces. The reflector shall be in the shape of a shallow frustrum of a pyramid. The bottom of the reflector shall be equipped with a pressure sensitive adhesive for attachment. The shell shall be molded of methyl methacrylate conforming to Federal Specification L-P-380c, Type 1, Class 3. The filler shall be potting compound selected for strength, resilience and adhesion adequate to pass the necessary physical requirements. The adhesive shall be pressure sensitive, 100 percent solids, 1.0 mm (0.040 in.) thick with closed cell release paper on the bottom. Pressure sensitive adhesive shall meet the requirements of adhesive tensile strength test.

Prismatic reflectors shall not be installed on bases until the adhesive in the pavement slots has properly hardened. All rust or foreign matter shall be removed from the surface of the base and the base shall be coated with a primer in accordance with the manufacturer's recommendations. The release paper shall be peeled from the butyl adhesive bottom of the reflector. The reflector shall be inserted into the recessed attachment area and a downward pressure of 667 N (150 lbs) shall be applied for 3 seconds.

2310

(1) Optical Performance. In order to perform the optical performance test, the following definitions shall apply. Horizontal incident angle shall mean the angle in the horizontal plane between the direction of incident light and the normal to the leading edge of the reflector. Reflective intensity shall mean candlepower of the return light at the chosen divergence angle for each 10.76 Lux (footcandle) of illumination at the reflector on a plane perpendicular to the incident light.

2320

A steel wool abrasion test shall be performed by forming a 25 mm (1 in.) diameter flat pad using No. 3 coarse steel wool in accordance with Federal Specification FF W 1825. The steel wool pad shall be placed on the reflector lens, a load of 22.7 kg (50 lbs) shall be applied, and the entire lens surface shall be rubbed 100 times.

After abrading the lens surface, the reflective intensity of each white reflecting surface at 0.2 degree divergence angle shall meet the following requirements when the incident light is parallel to the base of the reflector.

HORIZONTAL INCIDENT ANGLE	MINIMUM REFLECTIVE INTENSITY
0p	0.279 cd/lx 3.0 Candlepower/footcandle)
20p	0.1115 cd/lx 1/2 Candlepower/footcandle)

2330

The reflective intensity for yellow reflectors shall be 60 percent of the value for white. The reflective intensity for red reflectors shall be 25 percent of the value for white.

2340

A sample consisting of 100 markers shall be submitted and 23 will be tested. The reflectors to be tested shall be located with the center of the reflecting face at a distance of 1.5 m (5 ft) from a uniformly bright light source having an effective diameter of 7 mm (0.28 in.). The photocell width shall be an annular ring 9 mm (0.37 in.) inside diameter and 12 mm (0.47 in.) outside diameter and shall be shielded to eliminate stray light. The distance from light source center to the photocell center shall be 5 mm (0.21 in.). If a test distance of other than 1.5 m (5 ft) is used, the source and receiver shall be modified in the same proportion as the test distance. Failure of more than 4 percent of the sample's reflecting faces shall be the cause for rejection.

(2) Seal Test. A sample of 50 units shall be submerged in water at room temperature and subjected to a vacuum of 125 mm (5 in.) mercury for 5 minutes. After restoring atmospheric pressure, the units shall be left submerged for an additional 5 minutes. The unit shall be examined for water intake and failure of more than one unit shall be cause for rejection.

2350

(3) Heat Resistance Test. Three reflectors shall be tested for 4 hours in a circulating air oven at $80\text{p} \pm 3 \text{ pC}$ ($175\text{p} \pm 5 \text{ pF}$). The test specimens shall

be placed in a horizontal position on a grid or perforated shelf permitting free air circulation. At the conclusion of the test the samples shall be removed from the oven and permitted to cool in air to room temperature. After exposure to heat, the samples shall show no significant change in shape and general appearance when compared with corresponding unexposed control standards. Failure of one or more units shall be cause for rejection.

2360 **(4) Strength Test.** A random sample of three reflectors shall be selected for test purposes. The reflector base shall be positioned at the center of a flat steel plate which has a minimum thickness of 13 mm (0.5 in.) and a minimum outside diameter of 114 mm (4.5 in.). A load shall be applied to the top of the reflector through a 25 mm (1 in.) diameter by 25 mm (1 in.) high metal plug centered on the top of the reflector. The rate of loading shall be 5 mm (0.2 in.) per minute. The reflector will be rejected if there is either breakage or significant deformation of the reflector at any load of less than 8896 N (2000 lbs).

(5) Impact Test. The red lens shall not be subjected to impact test. A random sample of 20 lenses shall be selected from each lot of reflectors.

2370 The reflectors shall be placed in a convection oven at 55 °C (130 °F) for one hour. The reflectors shall be removed from the oven and the reflective face shall be immediately impacted by allowing a 0.2 kg (0.42 lbs) dart fitted with a 6 mm (0.25 in.) radius spherical head to drop 460 mm (18 in.) perpendicularly onto the center of the reflective surface. Cracks in the impact area shall be concentric in appearance. There shall be no more than two radial cracks longer than 6 mm (0.25 in.). There shall be no radial cracks extending to the edge.

2380 If 18 lenses of the test samples meet the above requirements, the lot shall be acceptable. Failure of 4 lenses of the sample shall be cause for rejection of the lot. If 3 lens fail, a resample of 20 additional lens shall be tested for failure. Failure of more than one lens of the resample shall be cause for rejection of the lot.

(6) Temperature Cycling Test. A random sample of 20 lenses shall be selected from each lot of reflectors. The samples shall be subjected to 3 cycles of 60 °C (140 °F) for 4 hours followed by -7 °C (20 °F) for 4 hours. There shall be no cracking nor delamination following temperature cycling.

2390 If 18 lenses of the test samples meet the above requirements, the lot shall be acceptable. Failure of four lenses of the sample shall be cause for rejection of the lot. If three lenses fail, a resample of 20 additional lenses shall be tested for failure. Failure of more than one lens of the resample shall be cause for rejection of the lot.

(7) Adhesive Tensile Strength Test. A standard 100 mm by 50 mm by 12mm (4 in. by 2 in. by 0.46 in.) reflector with pressure sensitive adhesive on the bottom shall be adhered to a flat 3.0 mm (0.12 in.) carbon steel test plate. The plate shall be primed in accordance with 913.14(d)1a, and the reflector shall be applied with a minimum application pressure of 41 kPa (60 psi). Both the top of the reflector and

2400 bottom of the flat plate shall have fastened to it an appropriate coupling device to ensure compatibility with the tensile testing device. The test sample shall then be tested in the tensile mode at 50 mm (2 in.) per minute pull rate. Minimum load to produce failure shall be 566 N (125 lbs) at 21 μ C (70 μ F). Any load below 566 N (124 lbs) is a failure and shall be cause for rejection of the lot.

(8) Basis for Use. The prismatic reflector shall be covered by a type B certification in accordance with 916.

2410 **b. Cast Metal Base.** The base shall be a ductile iron casting made of modular iron in accordance with ASTM A 536, Grade 70-50-05 hardened to 52-54 RHC. The cast iron base shall be marked with the manufacturer's name and model number. The maximum dimensions shall be 51 mm (2.00 in.) high, 152.0 mm (6 in.) wide and 254.0 mm (10.00 in.) long.

The exposed height of the casting after installation shall not exceed 13 mm (0.50 in.). The bottom of the casting shall have 2 parallel keels and a shaped web designed to fit into an accurately sawed, grooved slot in the pavement surface as shown on the plans.

2420 **(1) Epoxy Adhesive.** The epoxy adhesive shall be in accordance with AASHTO M 237, Type IV, Table 3 with respect to composition and performance. For sampling purposes, a batch shall consist of a single charge of all components into a mixing chamber.

(2) Basis for Use. A type B certification in accordance with 916 shall be furnished for the epoxy material. A type C certification in accordance with 916 shall be furnished for the cast metal base for the pavement markers.

2430 **c. Precast Cement Concrete Base.** The base shall be made of cement concrete with a compressive strength of 34.5 MPa (5000 lbs) when tested in accordance with ASTM C 39. The maximum dimensions shall be 51 mm (2.00 in.) high, 152.0 mm (6 in.) wide and 254.0 mm (10 in.) long. The maximum exposed height of the base after installation shall be 13 mm (0.50 in.).

(1) Adhesive for Precast Concrete Base. This adhesive shall be quick setting magnesium phosphate concrete patching material with high strength and high bonding qualities. This material shall be used between -1 μ C (30 μ F) and 32 μ C (90 μ F) and in thicknesses varying from 13 mm (1/2 in.) to full depth.

2440 The material may be a complete dry mix requiring only the addition of either water or a liquid activator just prior to mixing and use. The material shall not contain sufficient soluble chloride nor soluble sulfates to cause corrosion of reinforcing steel or damage to portland cement concrete.

The adhesive shall have an initial setting time of 10 minutes in accordance with ASTM C 266. The compressive strength shall be in accordance with ASTM C 109 and as listed.

TIME	COMPRESSIVE STRENGTH
2 hours	10.3 kMa (1500 psi) min
24 hours	27.6 MPa (4000 psi) min
7 days	41.3 MPa(6000 psi) min

The adhesive shall have a durability factor of not less than 80 after being subjected to 300 cycles of the freeze and thaw test in accordance with ASTM C 666, Procedure B.

The adhesive shall be suitable for use with hand tools and shall not require special curing procedures.

(2) Packaging. The patching material adhesive shall be packaged in strong moisture resistant bags or other suitable containers capable of withstanding normal shipping and handling without damage. The container shall protect the material from deterioration for a period of one year when stored in a dry condition. Mixing instructions shall be printed on each container.

(3) Basis for Use. A type C certification in accordance with 916 shall be furnished for the precast cement concrete base. A type B certification in accordance with 916 shall be required for the marker adhesive patching material.

2. Temporary Raised Pavement Marker. A temporary raised pavement marker shall consist of a shell, a reflective element and an adhesive. The shell shall be black or the same color as the pavement marking being supplemented or replaced. The reflective element shall be either a reflective prismatic lens or reflective sheeting. A uni-directional marker shall meet the visual requirements of this specification when viewed from the front of the marker and a bi-directional marker shall meet the visual requirements when viewed from either direction. Two unidirectional markers placed back to back are an acceptable alternate for a bi-directional marker.

The dimensions of the front view of the marker shall be as follows:

DIMENSION	MINIMUM	MAXIMUM
Width of marker shell	97 mm (3.8 in.)	
Height of marker shell without adhesive	13 mm (0.5 in.)	
Height of marker shell with adhesive		25 mm (1.0 in.)
Area of prismatic lens reflecting surface	194 mm ² (.30 in ²)	
Area of sheeting reflecting surface	645 mm ² (1.0 in ²)	

2490

a. Optical Requirements. The white and yellow reflective elements shall have the initial minimum reflectance values specified in the following tables when measured in accordance with ASTM E 809. The photometric characteristic to be measured shall be the coefficient of luminous intensity. This coefficient shall be expressed as candelas per lux (candlepower per footcandle). The entrance angle vertical component, Beta 1, shall be the clockwise angle formed from the vertical half plane, passing through the bottom front edge of the reflective element, to the face of the reflective element when viewed from the right side.

**TABLE 1
REFLECTIVE SHEETING ELEMENT FOR GRADE 2 MARKERS**

2500

Observation Angle (degrees)	Entrance Angle Horizontal Component Beta 2 (degrees)	Coefficient of Luminous Intensity Candelas/lux (Candlepower/foot candle)	
		White	Yellow
0.2	-4	0.0929 (1.0)	0.0558 (0.60)
0.5	-4	0.0372 (0.4)	0.0223 (0.24)

**TABLE 2
REFLECTIVE SHEETING ELEMENT FOR GRADE 1 MARKERS**

2510

Observation Angle (degrees)	Entrance Angle Horizontal Component Beta 2 (degrees)	Coefficient of Luminous Intensity Candelas/lux (Candlepower/foot candle)	
		White	Yellow
0.2	-4	0.0929 (1.00)	0.0558 (0.60)
0.5	+20	0.0372 (0.4)	0.0223 (0.24)
0.5	-4	0.0372 (0.4)	0.0223 (0.24)

TABLE 3
REFLECTIVE PRISMATIC LENS ELEMENT

Observation Angle (degrees)	Entrance Angle Horizontal Component Beta 2 (degrees)	Coefficient of Luminous Intensity (candelas/lux (Candle power/foot candle)	
		White	Yellow
0.2	+20	0.00372 (0.04)	0.0223 (0.24)
0.2	0	0.093 (1.0)	0.0223 (0.24)

The grade two marker does not require daytime visibility and target value. The shape, color and finish of the grade one marker shall provide an adequate diffused specular daytime signal. A diffused specular daytime signal will be considered adequate when the area of the horizontal projection, as determined from a point of projection of the front view of the marker less the projected areas of the reflective element and non-specular materials, is a minimum of 92900 mm² (144 in²). A minimum of 61900 mm² (96 in²) of this projection shall be attributable to that portion of the front view greater than 3 mm (0.125 in.) above the reference plane. For purposes of this requirement, the reference plane shall be the horizontal plane passing through the base of the marker and the point of projection shall be the point located 149.4 m (490 ft) horizontally in front of the marker and 1.1 m (42 in.) above the reference plane.

b. Strength Requirements. The marker shall withstand a 44.5 kN (10,000 lbs) load without cracking or permanent deformation. The testing procedure shall consist of centering a marker between the flat paralleled platens of a compression testing machine. A flat piece of 50-60 Shore A durometer rubber 150 mm by 150 mm by 10 mm (6 in. by 6 in. by 3/8 in.) shall be centered on top of the marker. The load shall be slowly applied through the rubber to the top of the marker. Failure shall constitute either cracking or permanent deformation of the marker at any load less than 44.5 kN (10,000 lbs).

c. Adhesive. The adhesive shall be compatible with the marker materials and shall not cause deterioration of the marker or concrete and asphalt pavements. The 3 types of acceptable adhesives shall be a pre-applied pressure sensitive adhesive, an adhesive pad or a bituminous adhesive.

The bituminous adhesive shall be used only on concrete pavement surfaces and on bituminous pavement surfaces which receive an additional pavement course of at least 19 mm (3/4 in.) thickness.

Pre-applied pressure sensitive adhesive shall be pre-qualified for use from a field evaluation.

The adhesive pad shall be sized to fit the marker's dimensions and shall consist of pressure sensitive, 100 percent solids, approximately 1.0 mm (0.04 in.) thick, with closed cell release paper on each side. The pressure sensitive adhesive, when applied with a minimum application pressure of 414 kPa (60 psi), shall possess a minimum tensile or shear strength of 103 kPa (15 psi) at 21 °C (70 °F) ambient air temperature. An adhesive primer shall be used to promote optimum adhesion when the adhesive pad is placed on old asphalt or concrete surfaces that have one or more additional courses. The adhesive primer shall be as recommended by the manufacturer of the adhesive pad. The adhesive primer shall not be used on the surface course.

The bituminous adhesive shall be applied using an appropriate melter or applicator and shall be in accordance with the following:

CHARACTERISTIC	REQUIREMENT
Specific gravity	1.80
Mass per cubic meter (Weight per cubic foot)	1762 kg (110 lbs)
Flash point per ASTM D 92	265 °C (509 °F)
Bitumen content per ASTM D 2172	25-30%
Filler content (by subtraction)	70-75%
Filler particle size	Over 85% passing 200 mesh sieve (75 µm)
Penetration at 25 °C (77 °F) per ASTM D 5	12 ± 4
Softening point (Ring & Ball) per ASTM D 36	105 °C ± 3 °C (221 °F ± 5 °F)
Recommended pouring temperature	204 °C - 218 °C (400 - 425 °F)
Shelf life	2 years
Packing	Silicone lined cardboard boxes containing approximately 28.1 kg (62 lbs) each

Note: Material shall not contain rubber polymers.

d. Acceptance Evaluation. Markers shall be prequalified for use and each manufacturer shall provide the Procurement and Distribution Division, Evaluation Unit with samples for a field evaluation. The Department will maintain a list of approved temporary raised pavement markers.

e. Basis for Use. Grade 1 and grade 2 markers furnished under this specification shall be covered by a type C certification in accordance with 916.

913.15 Traffic Signal Materials and Equipment.**(a) Traffic Signal Controller and Cabinet.**

1. Model Approval. Each model of controller and its cabinet will be tested, evaluated, and approved prior to use. Testing, evaluation, and approval will require a minimum of 6 months to perform. The period of evaluation will commence when the Department receives the preliminary product evaluation form accompanied by the product brochure, operational manual, maintenance manual, and documented theory of operation. The Procurement and Distribution Division will advise the manufacturer or vendor, in writing, of the date to deliver the controller and cabinet, for which model approval is requested, to the Procurement and Distribution Division. Certification in accordance with 913.15(a)6.f.(2), shall be received at the Procurement and Distribution Division a minimum of two weeks prior to the date of delivery of the controller and cabinet. Certifications in accordance with 913.15(a)6.f.(1), schematics for the controller and cabinet, operational manuals, theory of operation and parts lists shall be furnished with the controller when it is submitted to the Procurement and Distribution Division for evaluation and testing. The controller and cabinet will undergo the bench test in accordance with 913.15(a)4. A controller or control unit that fails the bench test procedure three times will be rejected and will not be placed upon the approved products list, nor will it be considered for future evaluation without documented changes to design. A list of approved models will be maintained by the Department. Only models from the approved list of control equipment in effect as of the date of letting, or as otherwise specified, shall be used in the contract. Continued failure and repeated malfunctions of an approved controller or control equipment shall be cause to remove that model from the Department's list of approved products.

A design change to an approved model of controller will require a resubmittal of the model for testing, evaluation, and approval. Permanent addition or removal of component parts or wires will be considered to be a design change.

2. Controllers or Control Units Furnished and Installed by the Contractor.

A controller with all components of equipment, necessary for an operating signal, wired into a cabinet will be a control unit. The Contractor shall prepare three packets for each control unit and provide these packets to the Engineer. Packet 1 shall consist of one complete set of wiring and schematic diagrams for the control unit and its appurtenances and a listing of model name/number and serial number of the removable equipment that can be readily exchanged or replaced, such as controller enclosure, controller modules, load switches, conflict monitor, detectors, and flashers. Packets 2 and 3 shall each consist of the same items as in Packet 1 plus a descriptive parts list and instruction and maintenance manuals that include the manufacturer's data sheets on each different type of I. C. chip being used, connection diagrams, voltage checks and the theory of operation. Each packet shall be labeled with the name of the intersection, the Contract Number, the Commission Number and the date of installation. Packet 1 will be forwarded to the Procurement and Distribution Division, packet number 2 will be retained in the controller cabinet, and Packet 3 will be retained by the District Traffic Office.

2650 The Contractor shall be responsible for all costs associated with vendor or manufacturer warranty service until acceptance of the contract, or acceptance of that portion of the contract where the traffic control equipment is installed.

3. Blank.

4. Bench Testing.

2660 The Department's Traffic Signal Control Bench Test Procedures, which are used for bench testing of traffic signal controllers, cabinets, and related equipment are on file and available upon request.

During bench testing a control unit will be considered as failed if one of the following conditions are encountered during the physical or operational test procedure:

- a. The controller unit skips intervals, or phases, places false calls, presents false indicator lights, does not follow the prescribed sequence or exhibits changes in timing beyond the tolerances of the specifications.
- b. The load switches produce incorrect signal indications.
- 2670 c. The conflict monitor fails to perform in accordance with the specifications of the requisition or contract.
- d. Auxiliary equipment such as pre-emptors, coordinators, or detectors do not operate in accordance with the specifications.
- e. The wiring for the interface of any items set out above is defective or incorrect.

2680 If the control unit fails the bench test procedure, the control unit shall be removed from the Procurement and Distribution Division for repairs and returned to the Traffic Support Center for retesting. The cover letter for the resubmittal of the control unit for retesting shall include an explanation of why the unit failed and what specific repairs were made.

A written test report will be provided for each control unit tested. A representative of the manufacturer or vendor may be present during the bench testing procedure.

2690 **5. Pretimed Solid State Digital Controller.** The following requirements are the minimum for the design and operation of a pretimed solid state digital, keyboard entry or keyboard entry backlit liquid crystal display menu-driven display type controller. The controller shall be capable of operating as a master or secondary control unit having four cycles, three offsets and four splits per cycle, and a minimum of four signal plans with individual control of 24 signal circuits, with an option of a total of 40 signal circuits, in each of 24 intervals. Controller, cabinet, and component parts shall be in

accordance with NEMA Standards TS-1, all provisions contained herein, and the Department's traffic signal control bench test procedures. The requirements herein and the test procedures shall govern over NEMA standards.

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a. General. The controller shall have a keyboard entry or keyboard entry backlit liquid crystal display menu-driven type with internal pre-emption, time base coordination, telemetry, printer, and interconnect modules. The controller unit shall contain a printer interface module, which permits a hard copy printout of all keyboard settings. The unit shall employ circuit designs, consistent with the latest techniques, using a microprocessor to implement the control logic.

The keystroke buttons shall be clearly marked as to function. The controller shall be programmable to permit initialization in any interval after a defined power interruption or reset by the conflict monitor.

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All data entry display windows shall be liquid crystal design. The display shall be a high resolution type display such that the display shall be readable on a plane located 0.6 m (2 ft) in front of, and parallel to, the display window. As a minimum, the display shall be readable throughout a vertical 60 degree angle that contains a minus 15 degree angle to a plus 30 degree angle measured from the horizontal line that is perpendicular to the center of the display window. Also, the display shall be readable throughout a horizontal 60 degree angle that contains a minus 15 degree angle to a plus 30 degree angle measured from the vertical line that is perpendicular to the center of the display window. The backlit liquid crystal display shall have a diffusion type lens or membrane to reduce its surface glare. All menu driven, data entry displays shall be backlit. The display for the menu driven controller shall be a minimum of four lines with 40 characters per line. All programming buttons and indicators pertinent to the operation of a phase shall be on the front of the controller. The display windows shall be capable of displaying the cycle length, offset, split, and any other variable functions or controller settings.

2720

Materials, conductors and component identification for all printed circuit boards shall be in accordance with NEMA Standards TS-1-14.2.3. Where practical, components shall be individually soldered directly to the printed circuit boards except for the memory elements, such as ROM, RAM, and PROM, which shall be socket mounted.

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All volatile memory chips and modules shall have battery back-up to protect any operator programmed data for a period of at least 60 days without 115 volt, 60 hertz AC input to the controller unit. Battery back-up may be achieved with either a rechargeable battery maintained in a charged state through a trickle charge or a nonrechargeable battery with a minimum shelf life of 10 years. Batteries shall be capable of being disconnected for shelf storage of the controller unit. An indicator shall be provided on the front of the controller to indicate that the battery is connected and operating properly. If a nonrechargeable battery is supplied, an indicator shall also be provided to show a low battery charge. The memory module, when removed from the mainframe, shall maintain all programmed data for at least 48 hours.

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Any external battery within the controller unit shall be turned off or disconnected during shipment and storage.

2750 All electrical components such as integrated circuit chips, transistors, diodes, triac, and capacitors shall be of such quality that they function properly under the environmental conditions experienced in field operation. All printed circuit boards shall be protected with a rosin coating. Fusing shall be on the front panel of the controller and shall provide protection to the controller from internal or external overload.

2760 The motherboard in the mainframe shall be capable of accepting all plug-in modules, including additional modules to provide for 40 signal circuits, necessary for the operation of the controller. All plug-in modules shall be equipped for easy removal or installation without the use of tools. All plug-in circuit boards shall be readily accessible for maintenance. Extender boards may be used for this purpose. As a minimum, all circuit boards shall be edge labeled with the first and last number, the first and last letter, and the first and last double letter if applicable, corresponding to the pin connector position. All modules shall each be removable without removing any other module. All hinges used shall have stainless steel pins.

2770 The controller unit shall be able to operate as a master controller or a secondary controller without requiring any changes in the unit itself. When used as a master controller, it shall not be required to program the units offsets to zero. The controller unit shall be capable of operating in an existing pretimed interconnected systems, which may have an electromechanical interrupter utilizing 115 volts, 60 hertz, AC. Cycle, offset, and split selectability shall be either by application of 115 volts, 60 hertz AC to the fuse panel or manually from the keyboard. Use of 115 volts AC Interconnect to a 24 volts DC logic interface is acceptable. As a minimum, the controller shall be capable of accepting nine conductors for interconnect, two conductors for cycle 1-4 selection, three conductors for reset 1-3 selection, two conductors for split 1-4 selection, and one conductor each for flash and common.

2780 With each controller unit and cabinet there shall be furnished three complete sets of wiring and schematic-diagrams, two descriptive parts lists, two instruction and maintenance manuals that include the manufacturer's data sheets on each different type of integrated circuit chip being used that has not been previously submitted to and on file at the Procurement and Distribution Division, connection diagrams, voltage checks and the Theory of Operation. The instructions manual shall contain explicit programming procedures for all required features and any additional features incorporated in the controller's design. All schematics shall also include numbered test points, where applicable, with operating voltages.

Serial number and model numbers shall be permanently applied on the face or front of all removable components of the controller where it is easily readable, without removing or disconnecting the component. Serial number and model number of the main frame shall be permanently applied externally near the front panel.

2790 **b. Controller Requirements.** The controller shall be capable of providing four cycle lengths with a minimum time setability from 10 to 255 seconds in increments of one second. Transfer from one cycle to another cycle shall occur at the end of the interval in effect at the time of request for transfer if that interval is programmed

for transfer. Cycle selection of any of the four cycles, from a remote location, shall be accomplished by use of no more than three conductors.

2800 The unit shall be capable of providing three individually programmable offsets for each cycle with a minimum time setability from 0 to 250 seconds in one second increments. The offset to be in effect shall be selected by activation of one of the three Reset inputs of the controller. Energization of a Reset input shall place that offset in effect independent of timing plan selection. Momentary de-energization, for a period of 3 to 5 seconds, of a Reset input shall define the system reference or synchronization.

The controller shall have program selected capabilities of a minimum of two methods of offset seeking transfer, shortway or dwell.

2810 Shortway offset transfer is the transfer from one offset to another by shortening or lengthening the permitted intervals of the signal plan so that no offset change may exceed 25 percent of the cycle length in one cycle. The new offset shall never be more than 50 percent away from the existing offset. The permitted intervals, whose duration may be varied, shall be specified in the signal plan. During shortway offset seeking, no interval shall time less than the minimum programmed, in the signal plan, for that interval.

2820 Dwell offset transfer is the transfer from one offset to another by holding in a programmed interval up to a maximum programmed duration. The controller shall be capable of programming the maximum dwell time between one and 250 seconds in one second increments. Only one maximum dwell interval shall be timed between transitions of Reset input lines. The unit shall be capable of accepting interrupter pulses.

The controller shall provide the capabilities of four splits for each programmed cycle. Each split for each cycle shall consist of a programmed number of intervals, variable up to a maximum of 24. If split transfer is programmable, transfer from one split to another shall occur in the intervals programmed to allow split transfer. If split transfer is not programmable, transfer shall occur at the zero point of the cycle. Split selection of any of the four splits, from a remote location, shall be accomplished by the use of no more than three conductors.

2830 A minimum of 24 signal intervals shall be provided for each combination of cycle and split. The intervals shall be individually programmable minimum time setability, selectable from 0 to 12.7 seconds in increments of 0.1 second or from 0 to 127 seconds in increments of 1.0 second for each cycle and split. The controller shall be capable of copying the timing values for any cycle and split into any other cycle and split in one operation.

If the controller can indicate time settings greater than required, the greater time settings shall be active when entered into the controller.

The controller shall be capable of implementing any one of up to four different signal plan sequences. The signal plan shall be either externally selectable by placing

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logic ground to the input terminal or manually selectable through the keyboard. During any controller cycle, it shall be possible to operate in any of the four signal plans, if the signal plans are compatible. Signal plan transfer shall occur in the next interval programmed for signal plan transfer. Each signal plan shall have at least one interval to enable safe transfer between signal plans. The controller unit shall operate in accordance with the programmed values for the selected cycle, offset and split, regardless of the signal plan in effect. Signal plan PROM programming shall effect the On-Off-Flash condition of the signal circuits, and minimum and backup timing of each interval.

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The unit shall provide the capabilities for a minimum of 2 detector inputs which can be programmed for Lock, Non-Lock, or Recall modes. The detector inputs shall provide a means to enter vehicle or pedestrian demand. When activated, these inputs may add intervals up to a total of 24 intervals to the cycle.

The unit shall provide the capabilities for a minimum of two preempt inputs. These inputs, either of which is activated, shall cause initialization of the selected preemption sequence which shall remain in effect until the input is removed.

2860

The controller unit shall have an internal time clock with capabilities of programming for time-of-day, day-of-week, and week-of-year. The time clock shall allow selection of cycles, splits and offsets through the time clock, the hardwire interconnect, the communication module, manual selection through keyboard entry, or a combination of these functions.

The controller shall have internal communication and telemetry with at least FSK 1200 Baud rate capable of transmitting on Bell 3002 four wire conductor with 600 ohm line impedance.

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The controller unit shall provide capabilities for the following inputs: Stop Timing, External Start, Start-up Flash, Interval Advance, Manual Control Enable, Remote Flash, and System or Computer Control.

Stop timing shall cause all timings to be discontinued. When stop timing is removed, timing shall resume from the point of interruption.

External start shall cause the controller to assume its programmed initialization conditions and commence normal operations upon removal of the input.

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Interval advance shall cause the controller to advance to the next interval in sequence, provided the manual control enable input is not energized. The actual advance shall occur on the trailing edge of the actuation. The duration of any interval shall be capable of being shortened without regard to the programmed minimum for the interval with the interval advance input active.

Manual control enable shall cause the controller to operate in the manual mode of operation. The transfer from automatic to manual mode operation and back to automatic operation shall occur immediately upon activation or de-activation of manual control enable.

2890

When operating in the manual mode, the same color sequence, as provided in automatic control, shall be displayed. Duration of all programmed variable intervals shall be controlled by operation of the interval advance input. Duration of programmed non-variable intervals shall not be less than the minimum time specified in the signal plan for such intervals. Operation of the interval advance input shall not advance the controller out of these intervals.

2900

Synchronization with the system shall be maintained during manual mode operation. When transferring back to automatic operation, the controller shall resume timing of the interval at the point in the selected timing plan that corresponds to the beginning of the interval being displayed when the transfer occurs.

Remote flash shall cause the controller to transfer to flashing operation when an AC+ signal is applied to the unit's fuse panel by an external source. The police panel switch shall cause the controller to go to immediate flash. Synchronization with the system master shall be maintained during flashing operation, if applicable. Upon de-activation of remote flash, transfer to cyclic operation shall be immediate and the unit shall display the interval that was programmed for exit from flash.

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System or computer control, when activated, shall control the duration of the programmed variable intervals, except when pedestrian or vehicle calls are not placed on the detector inputs.

c. Spare Modules. All spare modules shall be in accordance with the appropriate sections of this specification.

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d. Controller Enclosure. The enclosure shall be of adequate physical strength to protect the components during normal physical handling. Fusing, keypad, liquid crystal display, and input-output connectors required for the operation and standard field adjustments shall be mounted on the front panels.

The main frame shall be completely equipped and wired as a complete pretimed controller so that no additional hardware or wiring is required. The front panel of the controller shall be positively fastened to the frame. Special tools shall not be required to remove or replace modules or plugconnected printed circuit boards.

e. Power Requirements. The controller shall operate in accordance with NEMA Standard TS-1-2.

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f. Certification of Traffic Control Units. Certification of traffic control units shall be in accordance with 913.15(a)6f.

g. Warranty. The warranty for traffic control units shall be in accordance with 913.15(a)6g.

6. Traffic Actuated Solid State Digital Controller. The following requirements are the minimum for the design and operation of an 8 phase fully- actuated solid state, digital, menu-driven with backlit liquid crystal display controller. Controller,

2940 cabinet, and component parts shall meet NEMA Standards TS-1, all provisions contained herein, and the Department traffic signal control bench test procedures. The requirements herein and the test procedures shall govern over NEMA standards.

2950 **a. General.** The controller shall be keyboard entry, menu-driven with liquid crystal type display. The controller shall have internal preemption, time base coordination, telemetry, printer and interconnect modules. The microprocessor shall utilize nonvolatile memory devices. If "0" Powered Ram is utilized, the shelf life, with load, shall be a minimum of 10 years. Time base coordination shall use battery backed RAM to maintain the system clock and power outage. Any external battery within the controller unit shall be turned off or disconnected during storage and shipment. With each controller unit and cabinet, there shall be furnished three complete sets of wiring and schematic diagrams, two descriptive parts lists, two instruction and maintenance manuals that include the manufacturer's data sheets on each different type of integrated circuit chips being used that has not been previously submitted to and on file at the Procurement and Distribution Division, connection diagrams, voltage checks, and the Theory of Operation. The instruction manual shall contain explicit programming procedures for all required NEMA features and any additional features of which are incorporated into the controller design. All schematics shall also include numbered test points, where applicable, with operating voltages.

2960 Serial number and model numbers shall be permanently applied on the face or front of all removable components of the controller where it is easily readable, without removing or disconnecting the component. Serial number and model number of the main frame shall be permanently applied externally near the front panel.

b. Controller Requirements. The time settings shall be in accordance with NEMA Standards TS-1-14. If the controller can indicate time settings greater than required, the greater time settings shall be active when entered into the controller. A minimum of 2 maximum timing parameters shall be supplied on all phases of the controller and shall function when activated.

2970 The controller shall be capable of 2 through 8 phase programming and shall be capable of accepting an interrupter pulse on any coordinated phase.

Pedestrian timing shall be provided on all phases of a controller.

2980 The backlit liquid crystal display window shall consist of a minimum of 4 lines with 40 characters per line. The display shall be a high resolution type display such that the display shall be readable on a plane located 0.6 m (2 ft) in front of, and parallel to, the display window. As a minimum, the display shall be readable throughout a vertical 60 degree angle that contains a minus 15 degree angle to a plus 30 degree angle measured from the horizontal line that is perpendicular to the center of the display window. Also, the display shall be readable throughout a horizontal 60 degree angle that contains a minus 15 degree angle to a plus 30 degree angle measured from the vertical line that is perpendicular to the center of the display window. The backlit liquid crystal display shall have a diffusion type lens or membrane to reduce its surface glare.

The Time Base Coordinator shall operate such that the line function has the capability

to provide output for a minimum of four time of day functions during the same event time.

2990

Controllers shall be capable of servicing eight phases. The control unit, when delivered, shall be programmed to initialize in phase 2 and phase 6 green. The controller shall be keyboard programmable to permit initialization in any phase after a defined power interruption or reset by the conflict monitor. The following recall functions shall be a minimum and shall show functional status on the liquid crystal display.

3000

- (1) Lock detection
- (2) Maximum recall
- (3) Minimum recall
- (4) Non-lock detection
- (5) Pedestrian recall

Keystroke buttons shall be clearly marked as to function.

All indicators shall be liquid crystal design. All programming buttons and indicators pertinent to the operation of a phase shall be on the front of the controller. The controller shall have complete phase skipping capabilities. Dual ring, eight phase controllers shall have single entry operation.

3010

Controllers shall have keyboard programmable overlaps in accordance with NEMA Standards TS-1-14.3.7. All inputs and outputs from the controller shall be in accordance with NEMA Standards TS-1-13 and shall be accessible within the cabinet at the output terminal facility.

3020

All electrical components such as integrated circuit chips, transistors, diodes, triac, and capacitors shall be of such quality that they function properly under the environmental conditions experienced in field operation. All printed circuit boards shall be protected with a rosin coating. As a minimum, all plug-in circuit boards shall be edge labeled with the first and last number, the first and last letter, and the first and last double letter if applicable, corresponding to the pin connector position. Input-output pin connectors and MS connectors shall be as specified in NEMA Standards TS-1. Fusing shall be on the front panel of the controller and shall provide protection to the controller from internal or external overload.

c. Spare Modules. All spare modules shall be in accordance with the appropriate sections of this specification.

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d. Controller Enclosure. The enclosure shall be of adequate physical strength to protect the components during normal physical handling. Fusing, keypad, liquid crystal display and input-output connectors required for the operation and standard field adjustments shall be mounted on the front panels.

The main frame shall be completely equipped and wired as a complete 8 phase NEMA controller so that no additional hardware or wiring is required. The front panel of the controller shall be positively fastened to the frame such that no special tools shall be required to remove or replace modules or plug-connected printed circuit boards.

3040 **e. Power Requirements.** The controller shall operate in accordance with NEMA Standard TS-1-2.

f. Certification of Traffic Control Units. The following certifications shall be furnished in accordance with the applicable provisions of 916.

3050 **(1) Certification of a Production Run Model.** A Certification for a model of control unit shall be on file with the Department. A production run model shall be tested in accordance with, and comply with, all requirements of the NEMA Standards TS-1, Part 2, including shock and vibration. A certification of a production run model will be valid for a maximum period of 4 years from the date of testing or unless a significant change is made in the controller. If a significant change is made a new certification shall be submitted. A significant change shall be the addition or deletion of any function or feature in the control unit, or any major change to the circuitry in the control unit.

(2) Certification of Environmental Testing. A certification shall be furnished with each control unit approval indicating it has been tested and is in accordance with the following tests from NEMA Standards TS1-2.

3060 TS1-2.2.03- Test Procedure - Transients, Temperature, Voltage, and Humidity.
 TS1-2.2.04- Cabinet ventilation tests.
 TS1-2.2.07- Power interruption test.
 TS1-2.2.08- Timing accuracy tests.
 TS1-2.2.09- Signal conflict monitoring tests.

The cabinet requirements in 913.15(a)7 shall be applicable during the appropriate tests.

3070 The certification shall specify the model and serial number of the following components: cabinet, controller main frame, phase modules, ring modules, conflict monitor, load switches, flasher, and all specified auxiliary control equipment.

A complete log of each test for every controller shall be maintained. The log shall show which, if any, controller component failed during the test, when it failed, and what steps were taken to repair the controller. The log shall include the date of testing, name and title of person conducting the tests, a record of conditions throughout the tests, and a temperature and humidity vs time chart. The maximum revolution of any chart shall be 24 hours. The chart shall be from a recording machine used to monitor the status of the environmental chamber during testing.

3080 **g. Warranty.** A standard manufacturer's warranty shall be furnished for each traffic signal control unit which is furnished and installed. The effective date for the beginning of the warranty shall be the turn-on date shown on Form I.C. 636A. The warranty shall be provided prior to final acceptance.

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Each traffic signal control unit purchased by the Department shall have a minimum 2 year operational warranty or the manufacturer's standard warranty, whichever is longer. The 2 year warranty shall begin on the date the control unit is received at the Procurement and Distribution Division. The vendor or manufacturer shall be responsible, during the warranty period, for transportation costs to and from the Procurement and Distribution Division for items requiring warranty service.

Each traffic signal control unit purchased by the Department shall have a 2 year operational warranty. The 2 year warranty shall begin on the date the control unit passes the Traffic Signal Control Bench Test Procedures.

Continued failure and repeated malfunctions of an approved model of controller shall be cause to remove that model from the Department list of approved models.

3100

7. Cabinet Requirements for Traffic Signal Controllers.

a. General. The cabinet and the shelf, if needed, shall be fabricated of aluminum. The cabinet shall be 3 mm (0.125 in.) minimum thickness sheet aluminum or 6 mm (0.25 in.) minimum thickness die-cast aluminum. The cabinet exterior and interior including shelves, shall have a sandblasted, roughened, or chemically etched finish that reduces gloss, reflection, and glare.

3110

The main cabinet door shall use a Corbin Lock No. 2 and the lock shall be furnished with two No. 2 keys. The door shall be capable of being opened and stopped in at least the following two ranges of degree opening as measured from the face of the cabinet door on the hinged side, 80 to 100 degrees, and 150 to 180 degrees. The door shall be hinged on the left or right side of the cabinet.

The cabinet shall have a police door within the main door. The police door shall use a standard Corbin Police panel lock. The police door shall be weathertight. Two keys shall be furnished for the police door.

3120

In a cabinet used for a pretimed controller, the police door shall contain 3 separate switches for controller operation, one for automatic or manual, one for signal or flash, and one for signal on or off. A 6 mm (1/4 in.) phone jack receptacle shall be connected to the proper circuits for manual control of any signal interval. The switches shall be protected from water when the door is opened.

In a cabinet for actuated controllers, the police door shall contain two separate switches, one switch for master power cut-off and one switch to change automatic signal control to flashing control, or vice-versa. The switches shall be protected from water when the door is opened.

3130

The cabinet shall contain one duplex convenience outlet and a switch controlled lamp receptacle. The convenience outlet shall be duplex, three-prong, NEMA Type 5-15R grounding outlet in accordance with NEMA WD-6, with ground-fault circuit interruption as defined by the National Electric Code. These units shall be protected with a 15 amp cartridge fuse wired ahead of the multi-breakers.

3140 The cabinet shall contain a thermostatically controlled ventilating fan and a vent with a commercially classified uniform 25 mm (1 in.) thick filter. The vent size and filter size will be according to the provisions for the type of cabinet. The thermostat shall be manually adjustable from 21° to 38 °C (70° to 100 °F). The fan shall be mounted internally at the top and toward the front of the cabinet to exhaust out the front top lip of the controller. The fan shall be rated at a minimum of 2.83 m³ (100 ft³) per minute. The thermostat shall be located within 150 mm (6 in.) of the fan.

3150 The cabinet shall contain a surge arrestor. The surge arrestor shall be wired behind the multi-breaker, in parallel with the 35 amp circuit breaker signal buss and in series with the 10 amp circuit breaker for the solid state electronic equipment such as controller, conflict monitor and detectors. The surge arrestor shall have a maximum clamp voltage of 350 volts at a peak current of 20,000 amps for a minimum of 20 occurrences. The surge arrestor will operate between -34 °C to 74 °C (-30 °F to +165 °F). The dimensions of the unit shall not exceed 80 mm (3.25 in.) wide by 150 mm (6 in.) long by 64 mm (2.5 in.) deep.

Each inductive device, including the fan, shall have a separate power surge protection.

The terminals for AC + and - input to the cabinet shall be capable of accepting a No. 6 wire.

Test inputs A and B shall not be used for any purpose that will prevent interchangeability of controllers manufactured in accordance with these specifications.

3160 The manual flashing switch shall be wired to let the controller operate when the signals are flashing.

The cabinet shall contain a jack mounted type 3 solid state flasher in accordance with NEMA Standards TS1-8 or approved non-repairable unit in accordance with the NEMA Standards TS1-8 electrical and physical dimensions. Repairable flashers shall consist of opto or photo isolated solid state power relays.

3170 Remote flashing shall be provided for all signal circuits. Phases that the controller is to initialize in green, shall be wired to flash yellow. All other phases shall be wired to flash red. Flashing for signal circuits shall be as evenly balanced as possible on the circuits of the flasher controller.

3180 The cabinet shall be wired to activate the pedestrian timing, including load switches and all other necessary components. The pedestrian load switch and the signal load switch shall be a triple signal load switch in accordance with NEMA Standards TS1-5 or approved non-repairable units in accordance with the NEMA Standards TS1-5 electrical and physical dimension requirements. Repairable load switches shall consist of opto or photo isolated solid state power relays. The repairable load switch shall not use a printed circuit board to transmit the 115 volts AC line- in input or signal buss output. Each load switch shall have an indicator for each circuit indicating the status of the input to the load switch.

The load switch signal outputs shall be brought to a separate terminal strip for hook-up of the signal displays. Load switches shall be capable of being programmed for flash, overlap, vehicular, or pedestrian phases with the use of a standard slotted or phillips screw driver or standard nut driver. Programming of the load switches shall be accomplished on the front of the cabinet terminal facilities by installing or removing electrical conductors.

3190 The cabinet for a pretimed secondary controller used in a hardwired interconnect system shall contain a fuse block with a 2 amp fuse for the remote selection of each of the following inputs: Reset 1, Reset 2, Reset 3, Cycle 2, Cycle 3, Split 2, Split 3, and Flash. For an actuated controller, an additional input shall be provided for system or free operation. The fuse block shall have a 150 volt, 10 amp metal oxide varistor on the controller side of the fuse, connected to ground.

3200 The cabinet for a pretimed master controller used in a hardwired interconnect system shall contain a fuse block with a 6 amp fuse for the output selection of each of the following inputs: Reset 1, Reset 2, Reset 3, Cycle 2, Cycle 3, Split 2, Split 3, and Flash. For an actuated controller, an additional output shall be provided for system or free operation. The fuse block shall have a 150 volt, 10 amp metal oxide varistors for each of the output selections, on the controller side of the fuse, connected to ground. The fuse block shall also have a 1.0 K ohms, 30 watt resistor for each of the output selections, on the interconnect side of the fuse, connected to ground.

3210 The cabinet shall contain a main backpanel and supplementary backpanels, as needed. The model number of the main backpanel shall be permanently applied to the front of the backpanel, where it is easily readable, without removing or disconnecting the backpanel. Each controller input and output circuit shall terminate on the main backpanel or on a supplementary backpanel.

The cabinet shall contain auxiliary control devices such as conflict monitor, vehicle detectors, or other items specified. All terminal facilities and fusing within the cabinet shall be readily accessible for field connection without removing the controller or associated equipment. All equipment and terminals shall be readily accessible for maintenance in the cabinet. The backpanel shall be attached to the cabinet such that access to the backside of the backpanel, for maintenance purposes, shall be accomplished without the use of special tools or removal of auxiliary panels or other cabinet appurtenances.

3220 **b. G Cabinet.** The G cabinet shall be pedestal-mounted or pole-mounted. The bottom of the cabinet shall be reinforced to ensure a secure pedestal mounting. The G cabinet shall have dimensions of 635 mm (25 in.) wide, 965 mm (38 in.) high, 460 mm (18 in.) deep with a tolerance of + 100 mm (4 in.) in all dimensions.

A cabinet slipfitter shall be used to attach the cabinet to the pedestal. The slipfitter shall fit a 114 mm (4 1/2 in.) outside diameter pipe and shall have a minimum of three set screws equally spaced around the slipfitter.

3230

A vent of adequate size shall be provided. The size of the vent and the filter requirements shall be in accordance with the manufacturer's recommendations.

(1) Cast Aluminum Pedestal Base. A pedestal mounted G cabinet shall have a cast aluminum pedestal base. The cabinet and pedestal base shall be ground mounted on a concrete type A foundation at locations and dimensions as shown on the plans.

3240

The cast aluminum base shall be made of aluminum in accordance with ASTM B 179, alloy ANSI 319.1 or 319.2, or in accordance with ASTM B 26M (ASTM B 26), alloy ANSI 356.0-T6. The square base shall include an access door and anchor bolts with nuts and washers. The base shall be 8630 mm (13 3/8 in.) square and 380 mm (15 in.) in height 32 mm (1 1/4 in.). The weight shall be 10.0 kg \pm 2.2 kg (22 lbs \pm 5 percent).

3250

The base shall be designed to support a 68 kg (150 lb) axial load and 1.0 m² (11 ft²) of signal head area rigidly mounted. For design purposes, the distance from the bottom of the base to the center of the signal head area is 5.5 m (18 ft). In addition to the dead load, the base shall be designed to withstand wind and ice loads on the specified signal head area and on all surfaces of the support, in accordance with the AASHTO Standard Specification for Structural Supports for Highway Signs, Luminaires and Traffic Signals. Wind speeds used for design shall be based on a 10 year mean recurrence interval and a wind drag coefficient of 1.2 or as shown in the plans. The base shall contain an access door, which is 200 mm by 210 mm \pm 6 mm (8 in. by 8 1/4 in. \pm 1/4 in.) with a stainless steel hex head bolt for attaching the door.

3260

The base shall be attached to a foundation by four anchor bolts, with an anchor bolt circle of 324 mm (12 3/4 in.). Slotted lugs shall be integrally cast into the 4 corners of the base for attachment of the anchor bolts. The anchor bolts shall be steel in accordance to ASTM A 36M (ASTM A 36). The diameter of the anchor bolt shall be 19 mm (3/4 in.) with a minimum length of 460 mm \pm 13 mm (18 in. \pm 1.2 in.), plus 64 to 75 mm (2 1/2 to 3 in.) right angle hook on the unthreaded end. The top 100 mm (4 in.) of the bolt shall be threaded with 10 NC threads. The threads, plus 75 mm (3 in.), shall be coated after fabrication in accordance with ASTM A 153 or be mechanically galvanized and in accordance with the coating thickness, adherence, and quality requirements of ASTM A 153, class C. Each anchor bolt shall be provided with two hex head nuts in accordance with ASTM A 325M (ASTM A 325) and three washers. Two of the washers shall have a minimum 50 mm (2 in.) and maximum 54 mm (2 1/8 in.) outside diameter and be in accordance to ANSI B 27, Type B regular series and one shall be a nominal 19 mm (3/4 in.) series W washer, in accordance with ASTM F 436M (ASTM F 436).

3270

The cast aluminum pedestal base shall be in accordance with the dimensions and requirements shown in the plans. The casting shall be true to pattern in form and dimensions; free from pouring faults, sponginess, cracks, and blowholes; and free from other defects in positions affecting the strength and value of the intended use for the casting. The base shall not have sharp unfilleted angles or corners. The surface shall have a workmanlike finish.

The door and bolt for the door shall be interchangeable on cast bases from the same manufacturer.

3280

(2) Pedestal Pole. The top of the base shall accommodate a pole having a 114 mm (4 1/2 in.) outside diameter. The threads inside the top of the base shall be 100 mm (4 in.) national standard pipe threads. The pole shall be either a steel pedestal pole or an aluminum pedestal pole.

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A steel pedestal pole shall be a seamless schedule 40 carbon steel pipe in accordance with ASTM A 53, grade B. The pole shall have an outside diameter of 114 mm (4 1/2 in.). The pole shall weigh approximately 16 kg/m (10.8 lbs ft). The length of the pole shall be as shown in the plans. The pole shall have full depth national standard pipe threads on one end of the pole. The length of threads shall be 64 mm (2 1/2 in.). The pole shall be galvanized, after threading, in accordance with ASTM A 123. The threads shall be cleaned of all excess galvanizing and protected by a suitable shield.

3300

An aluminum pedestal pole shall be in accordance with ASTM B 241M (ASTM B 241) for seamless aluminum alloy, schedule 40, 6061-T6. The outside diameter of the pole shall be 114 mm (4 1/2 in.). The length of the pole shall be as shown in the plans. The pole shall weigh approximately 5.5 kg/m (3.7 lbs/ft). The pole shall have full depth national standard pipe threads on one end of the pole. The length of threads shall be 64 mm (2 1/2 in.) and protected by a suitable shield. The pole shall have a spun finish.

(3) Pole Cap. A pole cap shall be supplied for the top of the pole if the pole is used for the mounting of pedestrian signal faces or side mounted signal control cabinets. The pole cap shall be either a cast pole cap of aluminum or a pole cap of spun aluminum.

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A cast pole cap shall be made of aluminum, in accordance with ASTM B 179, alloy ANSI 319.1 or 319.2. The cap shall fit freely on the 114 mm (4 1/2 in.) outside diameter pole. A set screw using a 19 mm 3/4 in.) No. 12 hex head machine screw shall be supplied to hold the cap on the pole. A standard foundry draft will be allowed on the casting.

A pole cap made from spun aluminum shall be in accordance with ASTM B 209M (ASTM B 209), alloy 1100-0. The cap shall to fit tightly when placed on the end of the pole.

c. M Cabinet. The M cabinet shall be ground-mounted on a concrete foundation at locations and dimensions as shown on the plans.

The M cabinet shall have dimensions of 762 mm (30 in.) wide, 1219 mm 48 in.) high, and 406 mm (16 in.) deep with a tolerance of ± 50 mm (2 in.) in any or all dimensions.

3320

Anchor bolts shall be steel in accordance with ASTM A 36M (ASTM A 36). Diameter of the bolt shall be 13 mm (1/2 in.) or 16 mm (5/8 in.) and the minimum

length shall be 381 mm (15 in.) plus a 75 mm (3 in.) right angle hook on the unthreaded end. The top 150 mm (6 in.) of the bolt shall be threaded with 13 NC threads on 13 mm (1/2 in.) bolts and 11 NC threads on 16 mm (5/8 in.) bolts. The hexagon nut, the flat washer, and the threaded end of the bolt shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and in accordance with the coating thickness, adherence, and quality requirements of ASTM A 153, class C.

3330

If an interrupter is shelf mounted, a shelf shall be located a minimum of 305 mm (12 in.) from the top of the cabinet but shall have adequate room to easily install or remove the interrupter.

The vent shall have a uniform, 25 mm (1 in.) thick filter which may be of any of the following 3 sizes: 510 by 255 mm (20 by 10 in.); 405 by 255 mm (16 by 10 in.); or 405 by 200 mm (16 by 8 in.).

3340

The cabinet shall contain solid state load switches with incandescent lamp load rating of 1200 watts with nominal 120 volts 60 hertz which meet NEMA Standards TS1-5. Cabinets for pre-timed controllers shall contain a type 6 conflict monitor and cabinets for actuated controllers shall contain a type 12 conflict monitor. Conflict monitors shall be in accordance with NEMA Standards TS1-6. The conflict monitor upon sensing conflicting signal indications or unsatisfactory operating voltage shall transfer the signals to a flashing indication and the controller shall be wired to provide flash transfer if the conflict monitor is removed from service. Each channel of the conflict monitor shall have an indicator to show the channel's on or off status.

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A red failure indicator shall be provided, exclusively labeled red failure, and shall be continuously illuminated when red failure has occurred. The conflict monitor shall indicate the channel where red failure occurred by means of the channel indicator.

The phase arrangement of the controller shall coincide with the channel arrangement of the load switches and conflict monitor.

3360

The cabinet shall contain a multi-breaker with one 10 amp circuit breaker to provide overload protection to the controller, conflict monitor, and detectors and one 35 amp circuit breaker to provide overload protection to the signal and flash buss load. When both circuit breakers are in the off or tripped position, the signal output, the conflict monitor, and the controller shall be turned off. The signal shall be capable of operating in the flashing mode with the 10 amp circuit breaker OFF and the 35 amp circuit breaker ON. The controller, the conflict monitor, and the detectors shall be capable of operating with the 10 amp circuit breaker ON and the 35 amp circuit breaker OFF.

Two 1.0 microfarad 600 volts + 10 percent capacitors shall be installed on the output field terminal strip for left turn phases which are normally phases 1 and 3. One capacitor shall be connected from the green output terminal to AC negative terminal on each phase and the other capacitor shall be connected from the yellow output terminal to AC negative terminal on each phase.

3370

The cabinet shall contain a type 3 solid state flasher in accordance with NEMA Standards TS1, Part 8. The flashing output circuits carrying the signal load shall consist of opto or photo isolated solid state power relays. Programmable flash shall be provided for on the cabinet terminal facilities. No special tools shall be required to program flash. Flashing for even numbered phases shall be placed on one circuit and flashing for odd numbered phases shall be placed on the other circuit.

3380 The cabinet shall contain all terminal blocks, solid state load switch blocks, and harnesses necessary for the operation of the controller. It shall have two adjustable shelves with the first shelf located 380 ± 25 mm (15 in. \pm 1 in.) below the top of the cabinet and the second shelf located 178 mm (7 in.) below the first shelf. The cabinet shall contain 30 spare terminals. The spares shall be in one location and easily accessible in the cabinet. If vehicle detection is required for a controller, the spare terminals may be used for this purpose.

3390 Terminal strips shall be consecutively numbered and shall be in accordance with the schematic diagram. Numbering for terminal strips shall be neat and legible, silk screen type painting. All harnesses shall be of sufficient length to allow for the placement of the controller and conflict monitor at any location within the upper half of the cabinet. The shell of the cabinet connector harnesses shall be grounded. All relays and conflict monitors shall be encased in a protective covering to reduce the potential of electrical shock.

The police panel shall contain two separate switches. One switch for master power cut-off and one switch to change operation from automatic signal control to flashing control, or vice-versa. The switches shall be protected from water when the door is in the open position.

3400 **d. P-1 Cabinet.** The P-1 cabinet shall be ground mounted on a concrete foundation at locations and dimensions as shown on the plans with anchor bolts in accordance with 913.15(a)7c. The P-1 cabinet shall house an 8 phase traffic actuated solid state digital controller and shall have two adjustable shelves with the first shelf located 508 mm (20 in.) below the top of the cabinet and the second located 178 mm (7 in.) below the first shelf. The cabinet shall be 1118 mm (44 in.) wide, 1321 mm (52 in.) high, and 610 mm (24 in.) deep with a tolerance of ± 75 mm (3 in.) inches in all dimensions. Maximum exterior dimensions shall be 864 mm (34 in.) deep, 1194 mm (47 in.) wide, and 1600 mm (63 in.) high.

3410 The cabinet shall be in accordance with applicable provisions of 913.15(a)7a and 913.15(a)7c(2). It shall have one type 12 conflict monitor which shall be in accordance with NEMA Standards TS-1, Part 6.

Two 1.0 microfarad 600 volt, 10 percent capacitors shall be installed on the output field terminal strip for the left turn phases which are normally phases 1, 3, 5, and 7. One capacitor shall be connected from the green output terminal to AC negative terminal on each phase, and the other capacitor shall be connected from the yellow output terminal to AC negative terminal on each phase.

3420 The cabinet shall have a vent with a uniform 25 mm(1 in.) thick filter which may be of any of the following 3 sizes: 405 by 635 mm (16 by 25 in.); 380 by 510 mm (15 by 20 in.); or 405 by 510 mm (16 by 20 in.). It shall contain 40 spare terminals.

8. Two Circuit Alternating Flasher. Two circuit alternating flashers shall be solid state.

a. General. The solid state flasher shall periodically interrupt a source of alternating current line power. Solid state shall mean electrical circuits, the active components of which are semi-conductors, to the exclusion of electromechanical devices or tubes.

3430

The flasher shall be a type 3 solid state flasher conforming to Section 8 of the NEMA Standards Publication TS 1-1983. The flasher output circuit carrying the signal load shall consist of opto or photo isolated solid state power relays and shall be hard wired to the flasher connector.

Three schematic diagrams and three descriptive parts lists shall be furnished with each flasher.

3440

Two circuit alternating flashers shall be plug-in design. The flasher design shall not permit the unit to be inserted improperly into the plug-in base. The flasher shall have heavy-duty plugs and jacks capable of handling the rated load current. The rate of flash shall be 50 to 60 flashes per minute.

The flasher shall operate between 95 volts and 135 volts AC 60 Hertz. No degradation of performance shall be experienced in environmental changes from -29 °C to 74 °C (-20 °F to 165 °F) and 0 to 90 percent relative humidity.

3450

b. Cabinet Requirements. The cabinet shall be weatherproof and fabricated from cast aluminum or aluminum sheeting with a minimum thickness of 3.18 mm (0.125 in.). The cabinet door shall be the entire front of the cabinet and shall be hinged on the right or left side of the cabinet. A Corbin No. 2 lock and two No. 2 keys shall be furnished. The lock shall be located near the center of the door on the side opposite the hinge.

Minimum dimensions for the cabinet shall be 305 mm (12 in.) deep, 305 mm (12 in.) wide, and 305 mm (12 in.) high. The maximum dimensions shall be 460 mm (18 in.) deep, 380 mm (15 in.) wide, and 460 mm (18 in.) high.

3460

The cabinet shall have two pole plates for stainless steel band mounting of the cabinet on a pole with a minimum diameter of 100 mm (4 in.) and maximum diameter of 460 mm (18 in.). Two hub plates for 25 mm (1 in.) diameter conduit shall be provided with gaskets, eight bolts at four bolts per plate, nuts, and washers for attaching the hub plates to the cabinet. The cabinet shall be drilled for the mounting of the pole plates or hub plates as shown on the plans.

It shall have a screened vent in the bottom with a minimum size of 1129 mm² (1 3/4 in.²). A fan and thermostat shall be located in the top of the cabinet. The fan shall have separate power surge protection. The thermostat shall be located within 150 mm (6 in.) of the fan and shall be adjustable between 21° and 43 °C (70° and 110 °F).

The panel in the cabinet shall be capable of being removed and reinstalled with simple hand tools. A 25 amp radio interference filter and surge arrestor in accordance with 913.15(a)7a. wired ahead of a 15 amp circuit breaker shall be mounted on the panel. A terminal block capable of the following electrical connections shall be mounted on the panel.

Circuit 1-	for connection of field signals.
Circuit 2-	for connection of field signals.
AC plus-	can be attached to breaker if circuit breaker can accept a No. 6 wire.
AC minus lug-	capable of accepting a No. 6 wire.
Neutral lug-	capable of accepting a No.6 wire.
Fan Circuit-	adequately fused separately from circuit breaker with a fuse rating less than 15 amps.

(b) Interconnection Equipment.

1. Hardwire Interconnection.

a. Electro-Mechanical Dial Coordination Unit.

(1) General. The coordinating unit shall operate and be compatible with a 2 phase, 4 phase, and 8 phase controller in accordance with 913.15(a)6. It shall function in an interconnect system containing 3 dial electro-mechanical controllers and actuated controllers and shall contain 3 background cycles that are programmable in length of time and percentage split.

The dial coordinating unit shall generate a continuous background cycle. With an absence of vehicle actuation, recall operation, or pedestrian actuations, the traffic signal controller shall continue to rest in the coordinated phase. During periods of heavy vehicular demands, the coordinating unit shall not permit transfer of right-of-way to non-coordinated phase or pedestrian until the background cycle is in the predetermined position. When there is insufficient vehicular demand to extend the phase to the force-off limit the unit shall allow an early return to the coordinated phase.

The interface between the coordinating unit and the actuated controller shall provide a yield/force-off type of coordination. The coordinated phase or phases shall yield and the remaining phases shall be forced off. The coordination unit shall operate in a coordinated system with the number of controller phases specified. The interface

between the coordinator and the controller shall provide for Max I timing during coordinated operation. During noncoordinated, free run, operation, Max II timings shall be in effect.

The coordinating unit shall operate on 115 volt AC, 60 Hertz. It shall be shelf mounted and enclosed in a case with maximum dimensions of 483 mm (19 in.) wide, 191 mm (7 1/2 in.) high, and 200 mm (8 in.) deep. Three sets of wiring and schematic diagrams, three descriptive parts lists, and two instruction and maintenance manuals shall be furnished with each coordinating unit.

3520

(2) Additional Requirements for Master Locations. A master control unit shall include a dial coordinating unit interrupter and a dial coordinating unit master both compatible and able to function in an interconnected system containing 3 dial electro-mechanical controllers and actuated controllers.

The master control unit shall be capable of the following output selections: Reset 1, Reset 2, Reset 3, Dial 2, Dial 3, Flash, and coordinating free. The dial coordinating unit master and the dial coordinating unit interrupter shall have the following 5 cycle length gears for each dial:

3530

Dial 1	60-80-90-100-110 sec.
Dial 2 & 3	70-75-85-95-110 sec.

A master control unit shall contain a fuse block with a 6 amp fuse for the output selection of each of the following: Reset 1, Reset 2, Reset 3, Dial 2, Dial 3, Flash, Split 2, and Split 3. The fuse block shall have 10 amp metal oxide varistors for each of the output selections on the controller side of the fuse, connected to ground. The fuse block shall have 1000 ohm, 30 watt resistors for each of the output selections on the interconnect side of the fuse, connected to ground.

3540

(3) Additional Requirements for Secondary Locations. A secondary control unit shall contain a secondary dial coordinating unit compatible and able to function in an interconnect system containing 3 dial electro-mechanical and actuated controllers. The location shall be capable of the following input selections from a remote location: Reset 1, Reset 2, Reset 3, Dial 2, Dial 3, Flash, and coordinating free. Two switches within the secondary control unit shall be provided to manually select the following operations and labeled to show which operation is in effect. One switch shall select Dial 1, Dial 2, Dial 3, Time Clock or System. The other switch shall select Coordination or Free Run. secondary dial coordinating unit shall have the same 5 cycle length gears for each of the 3 dials as required by the master and interrupter dial coordinating units.

3550

(c) Blank.

(d) Signal Head Components.

1. Vehicle Signal Face. Vehicle signal faces shall be as shown on the plans. The components shall be in accordance with the latest standard of the Institute of Transportation Engineers for Adjustable Face Vehicular Traffic Control Signal Heads.

a. General. The signal faces shall be sectional in construction, requiring one section for each lens and furnished in the nominal size of 305 mm (12 in.) Each section of a face shall have a rectangular silhouette when viewed from the front or the rear.

b. Housing, Door, and Visor. The top and bottom of each housing shall have an integral locking ring with 72 serrations to permit rotation of the signal housing in 5 degree increments. Hub openings in the top and bottom of the signal housing shall accommodate standard 38 mm (1 1/2 in.) bracket arms. The thickness of the hub at the top and bottom of the housing shall be a maximum of 25 mm (1 in.) and a minimum of 10 mm (3/8 in.). The 305 mm (12 in.) door shall have two simple locking devices. The door on the hinged side shall be attached with hinge pins. Each lens shall have the standard cap type visor. All screws, latching bolts, locking devices, and hinge pins shall be stainless steel.

c. Lens. The lens shall be made of plastic and shall be in accordance with ASTM D 788, grade 8; ASTM D 702, grade 3; or ASTM D 3935. The index of refraction shall be between 1.48 and 1.59. The lens shall be uniformly colored throughout the body of the material, true to size and form, and free from any streaks, wrinkles, chips, or bubbles. The values of luminous transmission for the signal lens and the limits of chromaticity for the lens colors shall be in accordance with the latest standard of the Institute of Transportation Engineers for Adjustable Face Vehicular Traffic Control Signal Heads. The lens hole with the lens gasket in place shall be of sufficient size to accommodate a 305 mm (12 in.) diameter lens.

d. Reflector Assembly. The reflector shall be made of Specular Alzak Aluminum. The reflector assembly shall be designed so that it is pivoted and can be swung out of the housing and easily removed without the use of tools. A neoprene gasket shall be provided between and completely around the reflector and the reflector frame and shall be reusable. The reflector frame shall be aluminum or plastic.

e. Lamp Receptacle and Wiring. The lamp receptacle shall be fixed focus type, positioning the lamp filament at the correct focal point with respect to the reflector. The assembly shall be designed so the lamp socket can be rotated through 360 degrees into positions of adjustment for proper positioning of the lamp filament after relamping. The lamp socket shall be equipped with color coded wire either red, yellow, or green depending upon the lens color of the section. The socket wires shall be a minimum of 660 mm (26 in.) long, fixture wire No. 18 AWG or larger, 600 volts, with

3600 insulation designed to withstand 105 pC (221 pF). The conductor size, insulation type letter designation, and temperature rating shall be marked on the insulation or a material certification of compliance shall accompany each signal head combination. The wiring leads shall be terminated with screw spade lug type or female type connectors for ease of connection to the terminal block. The socket shall be equipped with a gasket to insure a dust tight fit between the socket and reflector.

f. Section Coupling. Any method to connect two or more sections together may be used, if the following requirements are met:

- 3610
- (1) Two or more sections, when jointed together, shall maintain structural integrity when loaded to Institute of Transportation Engineers Standards.
 - (2) The opening between joined sections shall accommodate two 13 mm (1/2 in.) cables.
 - (3) The maximum length of bolts used to connect sections together shall be 100 mm (4 in.).

3620 Nuts, bolts, or lock washers shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and be in accordance with the coating thickness, adherence, and quality requirements of ASTM A 153, class C.

g. Terminal Block. The yellow section of the 3 section signal head shall be equipped with a 5 position terminal block for termination of field wiring. Each section shall have provisions for addition of an 8 position terminal block or two 5 position terminal blocks or one 5 position and one 3 position terminal block. The terminal block shall have a minimum spacing between screw connections of 13 mm (1/2 in.). The height of the insulating ridge between screw connections shall be a minimum of 15 mm (19/32 in.) from the base of the terminal blocks.

3630

h. Material Requirements.

(1) Polycarbonate Signal Head. The housing, door, and visor of the section shall be made of ultraviolet and heat stabilized polycarbonate. The color shall be permanently molded into the components except the inside surface of the visor shall be painted non-reflecting flat black. The color shall be yellow in accordance with 909.02(b)4.

3640 **(2) Die-Cast Aluminum Signal Head.** The housing, door, and visor of the section shall be made of a die-cast, corrosion resistant, copper free, non-ferrous metal which shall be in accordance with ASTM B 85. All surfaces of the housing, doors, and visor shall receive a prime coat of zinc chromate paint in accordance with 909.02(a) or shall be anodized with a chromate aluminum oxide coating process. The finish shall be highway yellow enamel, two coats, oven baked and in accordance with 909.02(b) except the inside surface of the visor shall be painted non-reflecting flat black.

3650 **i. Certification.** A material certification in accordance with the applicable provisions of 916 shall accompany each order certifying that a signal head from a normal production run within the past 12 months, passed the Institute of Transportation Engineers criteria for breaking strength and deflection. Deflection testing is not required in the certification for polycarbonate signal heads.

3660 **2. Pedestrian Signal Head.** A pedestrian signal shall be one section and rectangular in shape. The dimensions of each side may vary from 460 to 485 mm (18 to 19 in.), including the visor and the hinges. The signal shall contain two figures with two different colored messages. The left figure shall transmit an upraised hand symbol message, and the right figure shall transmit a walking person symbol message. The pedestrian signal shall be in accordance with the standard of the Institute of Transportation Engineers for Pedestrian Traffic Control Signal Indications.

3670 **a. Housing, Door, and Visor.** The housing shall be equipped with mounting device hardware, such as clamshell, and round openings at top and bottom for mounting with brackets made of iron pipe standard, to fit the 38 mm (1 1/2 in.) pipe. The openings shall have a common vertical centerline through the housing to permit 360 degrees rotation after it is mounted. The openings shall have a serrated ring which permits locking of the housing in 5 degree increments throughout the entire 360 degrees of rotation. The brackets or the clamshell shall serve as the electrical conduit for the pedestrian signal. The housing shall be made of diecast, corrosion resistant, copper free, non-ferrous metal which shall be in accordance with ASTM B 85.

 The door on the front of the housing may be hinged from any side. The door shall be gasketed to maintain a weather-tight enclosure when secured to the housing. The door and the visor shall be made of the same material as the housing or of polycarbonate. All materials shall be clean, smooth, and free from flaws, cracks, blowholes, or other imperfections.

3680 The exterior of the housing shall be Federal yellow in color. The polycarbonate components shall be black in color impregnated throughout. The metal components shall be painted with enamel in accordance with 909.02(b).

 Each signal shall be provided with a visor. The visor shall consist of a minimum of 20 horizontal and 20 diagonal equally spaced louvers. Every other formed louver shall be reversed to provide diamond shaped cells each having a minimum area of 650 mm² (1 in.²). The louvers shall be made of impregnated black polycarbonate plastic processed with a flat finish on both sides, to eliminate sun phantom. The door and visor assembly shall be attached to the housing by means of stainless steel screws and nuts.

3690 **b. Optical Unit.** The optical unit shall consist of the redirecting lens, the lamp, a reflector, a filter, and other optical elements necessary for proper operation. The optical unit shall be designed to minimize the return of the outside light rays entering the unit, such as sun phantom. The optical unit shall be designed and assembled so that no light escapes from one message unit to the other.

The values of luminous transmission for pedestrian signal lenses and the limits of chromaticity for pedestrian signal colors shall be in accordance with the standard of the Institute of Transportation Engineers for Pedestrian Traffic Control Signal Indications.

3700

c. Lens. The lens shall be made of plastic. The lens shall be in accordance with ASTM D 788, grade 8; ASTM D 702, grade 3; or ASTM D 3935. However, the index of refraction shall be between 1.48 and 1.53. As required by the type of pedestrian signal, the lens shall be uniformly clear or colored throughout the body of the material, true to size and form and free from any streaks, wrinkles, chips, or bubbles.

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d. Message. When illuminated, the upraised hand symbol shall be in Portland Orange on the left surface of the signal indications. The walking person symbol shall appear in white on the right surface of the signal indication when illuminated. The upraised hand and walking person symbols shall each be a minimum of 280 mm (11 in.) in height. The width of the upraised hand symbol shall be a minimum of 178 mm (7 in.). The width of the walking person symbol shall be a minimum of 150 mm (6 in.). Message configuration, color, and size shall be in accordance with the standard of the Institute of Traffic Engineers for Pedestrian Traffic Control Signal Indications.

3720

e. Reflector Assembly. The reflector shall be a double parabolic type, made of textured polycarbonate plastic sheet coated with aluminum, or made of specular Alzak Aluminum with bead or flange on the outer edge to stiffen the reflector and ensure the true shape. The reflecting surface shall be free of flaws, scratches, defacements, or mechanical distortion.

The 2 sections of the reflector shall be divided by a full depth divider which properly mates with the message lens to effectively prevent light spillage from one section to the other.

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f. Light Distribution. The illuminated signal shall be uniformly illuminated over the entire message surface without shadows when viewed from usual angles encountered in service. The upraised hand and walking person symbols shall not appear to be illuminated portions of the lens. When not illuminated, the upraised hand and walking person symbols shall not appear to be illuminated by external light sources when viewed from the far end of the crosswalk. The pedestrian indication shall be visible to the pedestrian at all times at all distances from 3 m (10 ft) to the full width of the street to be crossed.

g. Electrical. The signal shall be equipped with a lamp and a socket for each of the 2 sections of the double parabolic reflector. The lamp receptacle shall be of heat resisting material. The lamp receptacle shall be provided with a grip to prevent the receptacle from working loose due to vibration. Each lamp shall be traffic signal lamp type A 21. The metal portion of the lamp receptacle shall be compatible with brass or copper.

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Each pedestrian signal shall be completely wired internally, and ready for connection of the field wiring. A suitable terminal block for connection of the internal wiring and the incoming field wires to the pedestrian signal head shall be provided in the signal housing.

The light source shall be designed and constructed so that if an electrical or mechanical failure occurs, the upraised hand and walking person symbols shall also remain dark.

3750

3. Disconnect Hanger Junction Box. Traffic signal disconnect hangers shall consist of a span hanger, a balance adjuster, a disconnect hanger clevis, and a housing with a hinged door with a positive latching device. The span hanger, balance adjuster, and all related hardware shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153. The housing shall be made of a die-cast, corrosion resistant, copper free, nonferrous metal which shall be in accordance with ASTM B 85. The balance adjuster fitting shall be made of ferrous or non-ferrous metal. When made of ferrous metal it shall be galvanized in accordance with the requirements for the components and related hardware as set out above.

3760

The disconnect hanger shall be designed so that the maximum allowable space or play between the span hanger and the eye-bolt of the balance adjuster and between the balance adjuster and the disconnect hanger clevis, at points where they are attached to each other by rivet pins or hex head bolts and nuts with lock washers, shall be 1.6 mm (0.062 in.). The span hanger bolt where the eye-bolt or the balance adjuster is attached shall be 16 mm (5/8 in.) diameter.

3770 When serrated locking rings are not integrally cast in the components, the component and locking ring shall be designed so that when the locking ring is placed flush against the component, the component and locking ring shall not rotate or slide when torque is applied. The serrated components shall have 72 serrations to permit rotation of the disconnect hanger clevis, hub plate, or signal head in 5 degree increments. There shall be no thread in contact with a wearing surface. Locking rings shall have a minimum thickness of 4.8 mm (3/16 in.) and a maximum thickness of 6.4 mm (1/4 in.) from the base of the ring to the serration peaks. The inside diameter shall be 50 mm (2 in.) and the outside diameter shall be 73 mm (2 7/8 in.).

3780 The terminal block shall have an 18 point terminal block permanently engraved or etched with sequential numbers indicating the circuits. The terminal block shall not have a method of connection which allows a screw point to damage wires when the wires are securely connected. Each point of connection shall accommodate a minimum of four No. 14 gauge (2.0 mm) wires.

The disconnect hanger shall have two side entrance holes on opposite sides capable of receiving a 38 mm (1 1/2 in.) plastic or rubber insert to reduce water infiltration. It shall be capable of supporting signal faces in the ambient temperature range of -35 °C to 49 °C (-35 °F to 49 °F) without failure.

3790 The balance adjuster shall have hex head bolts, lock washers, and nuts for securing the main body of the balance adjuster firmly onto and around the eye-bolt to prevent any twisting or turning of the head suspended below it. The span hanger shall have two J-bolts, lock washers, and hex head nuts adequate in size to securely fasten the hanger to a messenger cable up to 13 mm (1/2 in.) in diameter.

A type C certification in accordance with 916 shall be provided.

4. Signal Bulbs. The minimum design requirements for light bulbs to be used in a traffic signal face shall be in accordance with the Institute of Transportation Engineers standard for traffic signal bulbs and as follows:

3800

- a. Bulbs shall be 67 watt, 116 watt, or 150 watt for different kinds of indications, as specified below.

	INDICATION	WATTAGE
	230 mm (9 in.) pedestrian	67
	305 mm (12 in.) and 455 mm (18 in.) pedestrian	116
	200 mm (8 in.) red, yellow and green	67
	305 mm (12 in.) red	150
3810	305 mm (12 in.) yellow and green	116
	305 mm (12 in.) yellow and green arrows	150
	optically programmed heads	150

- b. All bulbs shall have medium size, brass bases.

c. Bulbs shall be designed for use in a horizontal position or a base-down position.

3820

d. The light center length shall be 62 mm (2 7/16 in.) for 67 watt bulbs and 75 mm (3 in.) for 116 watt and 150 watt bulbs.

e. The filament shall be C9 design with a minimum of seven supports. The 2 voltage supply leads may be counted as 2 of the seven supports.

f. The maximum, overall bulb length for 67 watt and 116 watt bulbs shall be 111 mm (4 3/8 in.) and for 150 watt bulbs shall be 120 mm (4 3/4 in.).

3830

g. All bulbs shall be clear and shall be 130 volt.

h. The 150 watt bulb shall be P25 or A21 size and shape.

i. The 67 watt and 116 watt bulbs shall be A21 size and shape.

j. All bulbs shall have 6000 hours minimum burning life.

5. Free Swinging Signal Support Assemblies.

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The maximum allowable space or play between the hanger assembly and the eyebolt of the balance adjuster and between the balance adjuster and the weatherhead clevis, at points where they are attached to each other by rivet pins or hex head bolts and nuts with lock washers, shall be 1.6 mm (0.062 in.). No bushings or shims will be allowed in this assembly.

The balance adjuster shall consist of a hex head bolt, a lock washer, and nuts for securing the main body of the balance adjuster onto and around the threads of the eye-bolt to prevent any twisting or turning of the adjuster.

3850

The span hanger, balance adjuster, weatherhead, and all related hardware shall be made of a non-corrosive metal or shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153. The weatherhead shall have a minimum of 64 mm (2 1/2 in.) of exposed threads. The weatherhead shall have two set screws to fasten the nipple to the weatherhead. If the weatherhead and threaded pipe has a slipin connection, the locking device shall be a double nut assembly. If the weatherhead and threaded pipe has a screw-in connection, the locking device shall be a double set screw assembly.

3860

The span hanger shall be furnished with two each of J-bolts, lock washers, and hex head nuts. The J-bolt shall be a minimum of 6.4 mm (1/4 in.) diameter and shall have sufficient threads to be able to secure the hanger to a 6.4 mm (1/4 in.) or a 13 mm (1/2 in.) messenger cable. The multiple pipe arm assembly shall consist of a span hanger assembly, a balance adjuster, a signal weatherhead, a 2, 3, or 4 way pipe arm, 38 mm (1 1/2 in.) pipe, a lower arm assembly, and all related hardware necessary for a complete assembly.

The 2, 3, or 4 way pipe arms shall have a minimum of 50 mm (2 in.) of exposed thread. Each arm of the pipe arm shall be furnished with two 72 serration locking rings. One locking ring shall have a 75 mm (3 in.) outside diameter and one locking ring shall have a 60 mm (2 3/8 in.) outside diameter.

3870

ASSEMBLY

MAXIMUM ALLOWABLE WEIGHT

2 Way	8.6 kg (19 lbs)
3 Way	11.3 kg (25 lbs)
4 Way	12.7 kg (28 lbs)

6. Mid-Mast Arm Mount Signal Bracket. The bracket shall permit the following 4 adjustments:

3880

- a. Rotational adjustment about bracket axis
- b. Vertical adjustment
- c. Rotational adjustment about mast arm
- d. Rotational adjustment right and left from vertical plane

The bracket shall be fastened to the supporting arm or structure with stainless steel bands. The bracket shall adjust to fit all sizes of round, octagonal, elliptical, or other shape structure without special tools or equipment.

3890

The bracket shall attach to the signal by clamping the signal head both top and bottom and shall be designed to accommodate the specified signal configuration. Each bracket shall be complete with all necessary hardware to attach the traffic signal to the bracket and the bracket to the support.

All electrical wiring shall be concealed within the bracket, except that which runs from the bracket to the mast arm.

3900

Upper and lower arms shall be cast from aluminum in accordance with ASTM B 26M (ASTM B 26), alloy 713.0-T5 or 356.0-T6. The vertical support tube shall be extruded from aluminum in accordance with to ASTM B 241M (ASTM B 241), alloy 6063-T6 or 6061-T6, and the strapping to attach the bracket to the arm shall be stainless steel. All steel or malleable iron parts shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153.

7. Pedestal Mounted Control Cabinets or Pedestrian Signal Heads. The pedestal base used for mounting pedestrian signal heads or control cabinets shall be in accordance with 913.15(a)7b(1). The length of the pedestal pole shall be as shown in the plans.

3910

(e) Signal Support.

1. Steel Strain Pole. The steel strain pole shall be an anchor base type pole and shall include a handhole and a pole top or cap. The poles shall be furnished in lengths specified.

3920 The pole shall have a reinforced handhole within 460 mm (18 in.) of the base. The minimum size shall be 130 mm (5 in.) by 200 mm (8 in.) with a cover and latching device. The pole shall have a top or cap with a set screw that can be removed with small hand tools.

 The pole material shall be in accordance with ASTM A 595 or A 572 with a minimum yield strength of 345 kPa (50,000 psi). The pole shall be galvanized after fabrication in accordance with ASTM A 123.

3930 All hardware, handhole cover and latching device, band type steel polebands, steel bolts, nuts, and washers shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153. All nuts and bolts, except anchor bolts, shall be in accordance with ASTM A 307. If a cast pole top or cap is used it shall be in accordance with to ASTM A 126 and shall be galvanized with a minimum coating of 0.610 kg/m² (2 oz/ft²).

3940 The polebands shall fit the pole as planned. The wire rope shall not be in contact with any 90 degrees edges or with any threads on the band. The pole band material shall be in accordance with to ASTM A 572M (ASTM A 572), grade 50; ASTM A 606; or ASTM A 36M (ASTM A 36) with minimum yield of 345 kPa (50,000 psi). The minimum width of the bands shall be 75 mm (3 in.) and the bands shall be capable of supporting the pole design load. Each half of the band shall be stamped with the corresponding size number.

 All welding shall be in accordance with 711.32. Welds shall generate the full strength of the shaft. Only longitudinal continuous welding shall be permitted on the pole shaft. Contacting joint surfaces shall be thoroughly cleaned before fabrication then completely sealed by means of welding. Shop drawings shall be submitted in accordance with 913.15(e)3i.

3950 The pipe coupling for the weatherhead and base plate shall be installed prior to galvanizing. The threads shall be cleaned of all excess galvanizing. An internal J-hook shall be installed near the top of the pole for wire support.

a. Maximum Load 35.6 kN (8000 lbs). The steel strain pole shall be capable of supporting an 35.6 kN (8000 lbs) load applied horizontally 460 mm (18 in.) below the top of the pole with a maximum allowable deflection of 4.1 mm (0.16 in.) per 445 N (100 lbs) of load. The pole shall be tapered 12 mm per meter (0.14 in. per foot) of length.

3960 A one piece base plate shall be secured to the base of the pole and shall develop the full strength of the pole. The base plate material shall be in accordance with ASTM A 36M (ASTM A 36), A 572M (A 572), or A 588M (A 588). The base plate shall have 4 holes of adequate size to accommodate 57 mm (2 1/4 in.) anchor bolts. The bolt circle shall have a 560 mm (22 in.) diameter and bolt square of 394 mm (15 1/2 in.).

3970 Four high strength steel anchor bolts, 57 mm (2 1/4 in.) diameter and 2,400 mm (96 in.) long, including the hook, shall be furnished with each pole. Each bolt shall have two hex nuts and two washers in accordance with ASTM A 307, grade A. The anchor bolt material shall be in accordance with ASTM A 576 or ASTM A 675M (ASTM A 675) with a minimum yield strength of 379 kPa (55,000 psi) or ASTM A 36M (ASTM A 36), special quality, modified to 379 kPa (55,000 psi) or approved equal. The threaded end of the anchor bolt shall have 305 mm (12 in.) of 4 1/2 NC threads and shall be galvanized the length of the threads, plus 75 mm (3 in.). The threaded end shall be coated after fabrication in accordance with ASTM A 153 or be mechanically galvanized and be in accordance with the coating thickness, adherence, and quality requirements of ASTM A 153, class C. The unthreaded end of the anchor bolt shall have a standard L bend for a distance of 230 mm (9 in.) from the centerline of the anchor bolt to the end of the L. In lieu of the standard bend a steel plate 2900 mm² (4 1/2 in.²) and 32 mm (1 1/4 in.) thick may be welded to the embedded end of the anchor bolt.

3980 **2. Wood Strain Pole.** Wood strain poles shall be made from southern yellow pine and shall be in accordance with the current ANSI Specifications and Dimensions for Wood Poles No. 05.1. They shall be of the length and class specified.

All poles shall be full length pressure treated by the full cell process in accordance with current specifications as set forth in the AWP Standards C1 and C4, using preservative as outlined in standard P5 and set forth in 911.02(g)2.

3990 Treatment, handling, and storage methods shall be in accordance with the current AWP Standards.

3. Signal Cantilever Structures.

a. General. A signal cantilever structure shall be designed in accordance with the latest AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, except where modified herein.

4000 Where the manufacturer has wind tunnel test data, he may use drag coefficients based on actual tests. Otherwise, the manufacturer shall use the drag coefficients in Table 1.2.5c.

b. Signal Support. The traffic signal pole and mast arm shall be designed to support the loads in accordance with the plans in an 129 km/h (80 mph) wind with gusts to 167 km/h (104 mph). Loading shall assume diecast aluminum heads.

4010 The traffic signal pole and mast arm shall be designed to provide a 5.3 m (17 ft) minimum clearance at all signals. Clearance shall be the vertical distance from the lowest point of the signal combination to a horizontal plane 75 mm (3 in.) below the base of the mast arm pole or from the lowest point of the signal combination to the pavement surface below the signal combination, which ever governs. Adjustment of the clearance at the installation site shall be by raising or lowering the mast arm along the upper length of the pole. After the pole is anchored to the foundation, the pole design shall permit the mast arm to be rotated 90 degrees in either direction and secured. The cable inlet shall not be obstructed when a field rotation or vertical adjustment of the mast arm is made.

There shall be no threads in the wearing surface plane at the point of connection between the clevis clamp and the signal face assembly. The clevis clamp shall have a 18 mm (11/16 in.) diameter bolt hole to receive the signal face assembly.

4020 **c. Combination Signal-Luminaire Support.** All requirements for a signal support shall apply to a combination signal-luminaire support.

The minimum design load of the luminaire shall be 24 kg (53 lbs) with a projected surface area subject to wind loading of 0.223 m² (2.4 ft²). If heavier or larger luminaires are used, their actual values shall be used. The required luminaire mounting height shall be in accordance with the plans. Mounting height shall be defined as the vertical distance from the lowest point of the luminaire to the horizontal plane which passes through the base of the pole.

4030 The maximum percentage of allowable stress shall be 80 percent of the AASHTO Standard Specifications for Group I loads. Vibration dampers shall be furnished as recommended by the manufacturer.

d. Pole Requirements.

(1) **General.** The pole shall be a round or multi-sided tapered tube, except the upper 1.2 to 1.8 m (4 to 6 ft) of a signal support pole may be nontapered. The signal support pole shall have a reinforced handhole 100 mm (4 in.) by 150 mm (6 in.) minimum complete with cover and latching device located 460 mm (18 in.) above the base. A 13 mm (1/2 in.) 13 NC threaded grounding nut or approved equivalent shall be provided and be accessible through the handhole. The pole cap shall be secured in place with set screws. The combination signal-luminaire pole shall have a reinforced handhole 100 mm (4 in.) by 200 mm (8 in.) minimum complete with cover and latching device, located 460 mm (18 in.) above the base. The combination signal-luminaire pole shall be provided with a removable pole cap and integral wire support hook for the luminaire electrical cable. The cable shall be attached to the hook by a service drop clamp. A wiring hole with a 25 mm (1 in.) to 38 mm (1 1/2 in.) inside diameter grommet shall be provided where the luminaire mast arm attaches to the pole.

(2) **Deflection.** The maximum allowable horizontal deflection of the pole under maximum loading conditions shall not exceed a deflection angle of one degree 10 minutes from the vertical axis of the pole for any 305 mm (1 ft) section of the pole along the entire length of the pole.

(3) **Materials.** The signal pole and the combination signal-luminaire pole shall be steel or aluminum. Steel poles shall be in accordance with ASTM A 595 or A 572 with a minimum yield strength of 345 kPa (50,000 lbs) and shall be galvanized in accordance with ASTM A 123. Aluminum poles shall be in accordance with ASTM B 221M (ASTM B 221) alloy 6063-T6 or 6005-T5, or ASTM B 241M (ASTM B 241), alloy 6063-T6.

(4) **Hardware.** All hardware for steel poles except bolts for the mast arm clamps and anchor bolts shall be in accordance with ASTM A 307 and shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to coating thickness, adherence, and quality requirements of ASTM A 153. A cast pole cap shall be in accordance with ASTM A 126 and shall be galvanized with a minimum coating of 0.610 kg/m² (2 oz/ft²).

All hardware for aluminum poles shall be stainless steel in accordance with ASTM A 276, type 304 or type 305.

(5) **Anchor Base.** A one piece anchor base shall be secured to the lower end of the pole and shall develop the full strength of the pole. The base shall be provided with 4 holes of adequate size to accommodate 32 mm (1 1/4 in.) anchor bolts equally spaced on a bolt circle of 380 mm (15 in.) diameter and shall have 4 tapped holes for attaching the bolt covers. Four removable bolt covers shall be provided with each base and each cover shall attach to the upright portion of the body of the base by means of one hex head cap screw. The steel for the anchor base shall be in accordance with ASTM A 36M (ASTM A 36), A 572M (A 572), or A 588M (ASTM A 488). Aluminum for the anchor base shall be in accordance with ASTM B 26, alloy 356.0-T6 or 356.0-T7 or ASTM B 209, alloy 6061-T6.

e. Arm Requirements.

(1) Signal Cantilever Arm. A signal cantilever arm shall be attached to the pole by circular clamps. One-half of the clamp shall be welded to the cantilever arm. The single member arm or the upper tapered member of the truss style arm shall have a cable inlet adjacent to the clamp complete with grommet. The cable inlet shall be a 44 mm (1 3/4 in.) diameter hole with a 38 mm (1 1/2 in.) inside diameter rubber grommet. The 6.1, 7.6 and 9.2 m (20, 25, and 30 ft) cantilever arms shall have one intermediate cable inlet with grommet located 3.7 m (12 ft) from the free end of the arm. The 10.7 and 12.2 m (35 and 40 ft) cantilever arm shall have two intermediate cable inlets with grommets located 3.6 m (12 ft) and 7.3 m (24 ft) respectively from the free end of the arm. The intermediate cable inlet shall be 25 mm (1 in.) diameter hole with 19 mm (3/4 in.) inside diameter rubber grommet.

The maximum rise of the single member arm shall be 13 mm (1/2 in.) per 305 mm (1 ft) of arm after loading. The maximum rise of the truss style arm shall be as set out in the table. The rise shall be measured vertically from the centerline of the free end of the truss to a plane through the centerline of the upper arm bracket after loading.

Mast Arm Length m (ft)	Total Rise m (ft - in.)	Tolerance mm (in.)
3.7 - 6.1 (12 - 20)	1.2 (4-0)	±25 (±1)
7.6 (25)	1.3 (4-3)	±25 (±1)
9.2 - 12.2 (30 - 40)	1.4 (4-7)	± 25 (±1)

The end signals on the truss style arms shall be suspended and the intermediate signals shall be rigidly attached. All signals on the single member arms shall be rigidly attached as shown on the plans. The cantilever arms shall be used as an enclosed raceway for wiring and shall be free of burrs and rough edges.

Both parts of the clamp for the single member arms shall be stamped with the arm length prior to galvanizing.

(2) Luminaire Mast Arm for Combination Support. The luminaire mast arm shall be in accordance with 913.11(a)1.

(3) Materials. The signal mast arm shall be of the same material as the pole. The luminaire mast arm shall be of the same material as the pole except that a truss type arm shall be in accordance with 913.11(a). Bolts for the mast arm clamp shall be stainless steel in accordance with ASTM A 276, type 304 or 305.

f. Anchor Bolts. Four steel anchor bolts, each fitted with two hex nuts and two flat washers, shall be furnished with each pole. The anchor bolt shall be one 32 mm (1 1/4 in.) diameter with a minimum of 254 mm (10 in.) of 7 NC threads on the upper end. The threads, nuts, and washers shall be galvanized in accordance with ASTM

4130 A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153. The anchor bolt shall be 1220 mm (48 in.) long with a 100 mm (4 in.) right angle bend on the lower end or a square steel washer, 150 mm by 150 mm by 13 mm (6 in. by 6 in. by 1/2 in.), with a hex nut welded onto the lower end. The steel for the bolt shall be in accordance with ASTM A 576 or ASTM A 675M (ASTM A 675), with a minimum yield strength of 379 kPa (55,000 psi), or ASTM A 36M (ASTM A 36), special quality, modified to 379 kPa (55,000 psi) or approved equal.

g. Finish. All steel material shall be fully galvanized. Galvanizing shall take place after all welding is accomplished. Aluminum poles shall be provided with a satin finish accomplished by mechanical rotary grinding and aluminum mast arms shall be provided with a satin etched finish.

4140

h. Certification. Unless otherwise specified, all materials covered herein shall be covered by a type C certification in accordance with 915.

i. Shop Drawings. Five sets of shop drawings and a set of design calculations shall be submitted to the Division of Design for approval. A copy of the transmittal letter shall be sent to the Engineer. The approved drawings will be distributed by the Division of Design.

4150 **4. Downguys, Anchors, Rods, and Guards.** Pole anchors shall be 8 way expanding with a minimum area of 87,100 mm² (135 in.²) when expanded or a 250 mm (10 in.) diameter screw anchor. They shall have a minimum holding strength of 44.5 kN (10,000 lb). They shall be painted and in accordance with ASTM A 569M (ASTM A 569). Anchor rods for expanded anchors shall be 19 mm (3/4 in.) diameter steel and for screw anchors shall be 32 mm (1 1/4 in.) diameter steel, 2.4 m (8 ft) long, in accordance with ASTM A 659M (ASTM A 659), and be galvanized in accordance with ASTM A 153.

4160 Guy guards shall be made of 18 gauge galvanized steel, polyethylene, polyvinylchloride, or melamine phenolic, and shall be 2.1 m (7 ft) long. The steel guy guard shall have a tight gripping, non-scarring hook for quick attachment to the guy wire. The bottom shall have a clamp that fits over the anchor rod and securely grips by tightening the bolt. Steel guy guards shall be in accordance with ASTM A 659M (ASTM A 659). The nonmetallic guy guard shall be a helical pigtail which shall resist upward movement, a lock strap to secure the lower end, and a guy guard sleeve. Non-metallic guy guards shall be gray or yellow.

(f) Messenger Cable.

4170 **1. Messenger Cable.** Messenger cable shall be zinc-coated steel wire strand, contain seven wires, and have a nominal diameter of 10 mm (3/8 in.). The cable shall be in accordance with ASTM A 475, Siemens-Martin Grade.

2. Span, Catenary, and Downguy Cable. Span, catenary, and downguy cable, shall be aircraft cable for non-aircraft use, and shall be 10 mm (3/8 in.) nominal diameter, made of stainless steel wire, and consist of seven, 19 wire flexible steel strands. The 10 mm (3/8 in.) cable shall have a minimum breaking strength

of 53.4 kN (12,000 lb). It shall be in accordance with Military Specifications MIL-W-1511.

4180

3. Tether and Support Cable. Tether and support cable shall be aircraft cable, for non-aircraft use, and shall be 3 mm (1/8 in.) nominal diameter, made of stainless steel wire, and consist of seven, 7-wire flexible steel strands. The 3 mm (1/8 in.) cable shall have a minimum breaking strength of 7560 N (1700 lbs). It shall be in accordance with Military Specifications MIL-W-1511.

4. Cable Hardware.

4190

a. Messenger Hangers. Messenger hangers shall be either a three bolt clamp or a 10 mm (3/8 in.) by 44 mm (1 3/4 in.) steel hanger with a 90 degree bend extending from the pole 95 mm (3 3/4 in.). The hanger shall have a curved groove and clamp capable of receiving a 8 mm to 13 mm (5/16 in. to 1/2 in.) cable.

The messenger shall be clamped by two 13 mm (1/2 in.) high carbon steel bolts. The angle hanger shall be mounted with a 16 mm (5/8 in.) through bolt and a 13 mm (1/2 in.) lag screw. The three bolt clamp shall be mounted with a 16 mm (5/8 in.) through bolt. The angle hanger shall be in accordance with ASTM A 575. The bolts shall be in accordance with NEMA PH 23.

4200

b. Cable Ring. Cable rings shall be galvanized steel in accordance with IMSA 51-1.

c. Clamps. Clamps shall be made of 10 mm (3/8 in.) steel and in accordance with ASTM A 575.

Two bolt clamps shall be a minimum of 95 mm (3 3/4 in.) long and 32 mm (1 1/4 in.) wide with two 13 mm (1/2 in.) bolts which shall clamp cable of 3 to 13 mm (1/8 to 1/2 in.) diameter.

4210

Three bolt clamps shall be a minimum of 150 mm (6 in.) long and 42 mm (1 5/8 in.) wide with three 16 mm (5/8 in.) bolts which shall clamp cable of 8 mm to 13 mm (5/16 to 1/2 in.) diameter.

The bolt heads shall be large enough to provide maximum clamping area and shall have oval shoulders to prevent the bolts from turning while tightening. The bolts shall be in accordance with NEMA PH 23.

4220

d. Servi-Sleeves. Servi-sleeves shall be 32 mm to 57 mm (1 1/4 to 2 1/4 in.) in length and shall hold the size of the cable specified. The sleeves shall be in accordance with ASTM A 659M (ASTM A 659).

e. Straight Eye-Bolts. Straight eye-bolts shall be 19 mm (3/4 in.) diameter drop forged steel, a minimum of 356 mm (14 in.) long, and have 150 mm (6 in.) of thread. The steel washers shall be 57 mm (2 1/4 in.) by 57 mm (2 1/4 in.) by 5 mm (3/16 in.) in size with 21 mm (13/16 in.) hole in the center. All parts shall be in accordance with ASTM A 575 and shall be galvanized in accordance with ASTM A 123.

f. Hub-Eyes. Hub-eyes shall be made of drop forged steel and in accordance with ASTM A 575. They shall receive a 19 mm (3/4 in.) mounting bolt and have a full rounded thimble eye for protection of the guy cable.

4230

5. Signal Cable.

a. Hook-up Wire. Signal hook-up wire shall be stranded one conductor wire, type THW 7 strand No. 14 AWG, with a thermoplastic sheath 1.19 mm (3/64 in.) thick and a 600 volt rating. Insulation shall be color coded, as required, and labeled with gauge, voltage rating, and insulation type.

4240 **b. Signal Control Cable.** Signal control cable shall be in accordance with IMSA 19-1 or 20-1 and shall be stranded No. 14 AWG wire.

c. Integral Messenger Interconnect Cable. Integral aerial interconnect cable shall be figure "8" self-supporting type cable consisting of a messenger cable and 7 conductors No. 14 AWG signal cable in accordance with IMSA 20-3.

4250 **d. 6 Pair/19 Telemetry Cable.** 6 pair telemetry cable shall contain six twisted pairs of 19 gauge conductors and shall be in accordance with IMSA Specification 40-2 for underground application and IMSA Specification 40-4, integral messenger, for aerial application.

4260 **e. Fiber Optic Interconnect Cable.** Fiber optic cable shall contain four stranded multimode, graded index, optic fibers with a minimum of one non-metallic central strength member. The cable shall be loose tube, all dielectric construction, suitable for outdoor use in conduit or on aerial supports. Each individual fiber shall be 62.5/125 μ m diameter, core/clad, and each fiber shall be individually encased in its own gel-filled color-coded buffer. The fiber optic cable shall be constructed with Kevlar braid and outer polyethylene jackets as a minimum. If an inner jacket is used it shall be PVC. Maximum attenuation of the cable shall be 4.0 dB/km nominal, measured at room temperature at 850 nm. The bandwidth shall not be less than 160 MHz/km, also at 850 nm. Each fiber shall be continuous with no factory splices except for joining standard length cables to form longer, continuous jacketed cable to fit installation requirements. The cable shall have standard nylon rip cords. Kevlar rip cords will not be accepted. The cable shall be in accordance with the generic requirements for optical fiber and optical fiber cable per Bellcore Technical Reference TR-TSY-000020.

4270 The exterior of the polyethylene outer cable jacket shall be stenciled so that every fifth meter on each reel is marked with a number. The fifth meter of each reel shall be marked with a 5, the tenth meter marked with a 10, and so on until the end of the reel. The stencil shall be applied to the outer jacket using permanent ink and shall be permanently engraved into the jacket to provide long lasting readability.

f. Service Cable. Traffic signal service cable shall be color coded, stranded copper No. 8 AWG wire, 3 conductor cable, type THWN.

g. Detection Wire and Sealant.

4280 **(1) Loop Detector Lead-in Cable.** Loop detector lead-in cable shall be in accordance with IMSA 50-2 and shall be stranded 2 conductor No. 16 AWG, 19 strands of No. 29 wire.

The nominal capacitance between conductors shall be 187 pF/m (57 pF/ft) and 322 pF/m (98 pF/ft) between one conductor and the other conductor connected to the shield.

(2) Roadway Loop Wire. Roadway loop wire shall be 14 AWG gauge IMSA 51-5 duct-loop wire with polyvinyl chloride outer jacket of 6.3 mm (1/4 in.) diameter.

(3) Sealant. Prior to installing roadway loop wire in the roadway saw cuts, the saw cuts shall be cleaned in accordance with the requirements for the joint sealant to be used. After proper cleaning and installation of the loop wire, the saw cut shall be sealed with a joint sealant material in accordance with 906.02(a)1 or 906.02(a)2. The joint sealant material to be used shall be compatible with the roadway materials. The joint sealant shall be installed in accordance with the applicable sealant specification. However, the joint configuration shall not apply. A copy of the sealant manufacturer's written application instructions shall be submitted to the Engineer prior to any sealant operations. If the Contractor elects to use a sealant complying with 906.02(a)2, the sealant material shall be heated in a kettle or melter constructed as a double boiler with the space between the inner and outer shells filled with oil or other heat-transfer medium. This melter shall have a positive temperature control and a mechanical agitator. A backer rod shall be used for both cold applied sealants and hot poured sealants. The sealant material shall fill the saw cut as shown on the plans. All significant or objectionable surplus joint sealant on the pavement surfaces shall be promptly removed.

h. Ground Wire. The ground wire shall be copper wire No. 6, AWG soft-drawn, solid copper in accordance with ASTM B 3.

i. Splicing Kit. Splicing kits shall contain a two piece, transparent snap-together mold body and include an epoxy and sealing compound contained in a unipak. It shall be capable of insulating and splicing nonshielded cables rated up to 5 kilovolts and multi-conductor cables rated up to 600 volts.

(g) Ground Rod and Connections. Ground rods shall be 13 mm (1/2 in.) in diameter by 2.4 m (8 ft) long with a machined point and chamfered top. They shall be made of steel with a molecularly bonded outer layer of electrolytically applied copper. The finished rod shall be cold-drawn and shall have the following minimum physical properties:

PHYSICAL PROPERTY	MINIMUM
tensile strength	668 MPa (97,000 psi)
yield strength, 0.2% offset	58.61 MPa (85,000 psi)
% of elongation	90 kPa (13 psi)

The ground rod and wire connection shall be made by a thermo weld process or approved equal. The welding material shall cover and secure the conductor to the rod and shall be porous free.

An acceptable alternate shall be a ground grid connection properly sized and shall consist of a shear head bolt, a "C" shaped body, nest, and wedge. The connector components shall be fabricated from aluminum-bronze alloy, silicone-bronze alloy, and copper.

(h) Castings for Handholes. The ring and cover for handholes shall be in accordance with 910.05(b).

(i) Entrance Switch. The entrance switch shall be a single pole, 50 amp, 120 volt circuit breaker in a NEMA type 3R enclosure. The minimum dimensions of the enclosure shall be: width 127 mm (5 in.), depth 95 mm (3 3/4 in.) and height 235 mm (9 1/4 in.). A 25 mm (1 in.) rain-tight detachable hub shall be supplied in the top of the enclosure. The enclosure shall have knockouts on the sides, bottom and back with diameters of 22 mm (7/8 in.) to 44 mm (1 3/4 in.). The enclosure shall contain the circuit breaker, an insulated solid bar for connection of AC Neutral, a separate lug for attachment of earthground, have provisions for a padlock, and shall be surface mounted.

The enclosure shall be made of galvanized steel with a rust inhibiting treatment, and finished in the manufacturer's standard color of baked enamel.

(j) Conduit and Fittings.

1. Steel Conduit. Steel conduit shall be 50 mm (2 in.) nominal diameter, threaded with a steel coupling on one end meeting applicable requirements for the conduit and the other threaded end protected by a suitable shield. The conduit shall be made of mild steel or intermediate steel. Mild steel conduit shall be in accordance with ANSI C

80.1 and UL 6. Intermediate steel conduit shall be in accordance with UL 1242, ASTM A 513 or ASTM A 135. Conduit shall be hot dipped galvanized on the interior and exterior surfaces in accordance with ANSI C 80.1.

4360 The various conduit fittings such as bands, elbows, bodies, straps, lock nuts, and threadless connectors, shall be in accordance with Federal Specifications W-F-408. Conduit bends, elbows, and bodies shall be threaded, made of malleable iron, and galvanized. Conduit straps shall be two hole straps with a minimum thickness of 3 mm (1/8 in.) and shall be made of steel which is galvanized in accordance with ANSI C 80.1. Conduit lock nuts 10 mm to 38 mm (3/8 in. to 1 1/2 in.) in size shall be made of steel. Other sizes shall be made of malleable iron. All nuts shall be galvanized.

2. Polyvinyl Chloride Conduit. PVC conduit shall be in accordance with schedule 40 conduit in ASTM D 1785. The PVC conduit fittings shall be in accordance with ASTM D 2466. Each length of pipe shall include a coupling.

4370 **(k) Detector Housing.** The entire housing casting shall be made from aluminum alloy in accordance with ANSI 320.

(l) Certification. Unless otherwise specified, all materials covered herein shall have a type C certification in accordance with 916.

913.16 Fabric for Waterproofing. Fabric for waterproofing shall be treated cotton in accordance with AASHTO M 117, woven glass in accordance with ASTM D 1668, or glass fiber mat in accordance with ASTM D 2178. Material furnished under this specification shall be covered by a type C certification in accordance with 916.

4380 **913.17 Packaged, Dry, Combined Materials for Mortar and Concrete.** These materials shall be in accordance with ASTM C 387. All packages shall be identified as conforming to ASTM C 387. The markings shall also show the kind and type of material, the net weight in each bag, the yield in cubic meters (cubic feet) or yield in square meters per millimeter (square feet per inch) of thickness, and the amount of water recommended for mixing to produce a 50 mm to 75 mm (2 in. to 5 in.) slump.

4390 **913.18 Geotextile for Use Under Riprap.** The material used shall consist of strong, rot resistant, chemically stable long-chain synthetic polymer material dimensionally stable with distinct and measurable openings. The plastic yarn or fibers used in the geotextile, shall consist of any longchain synthetic polymer composed of at least 85 percent by weight of polyolefins, polyesters, or polyamides, and shall contain stabilizers and inhibitors added to the base plastic to make the filaments resistant to deterioration due to ultraviolet and heat exposure. The geotextile shall be calendared or otherwise finished so that the yarns or fibers will retain their relative position with respect to each other. Slit film geotextiles will not be permitted unless approved.

The geotextile shall meet the following physical requirements:

GEOTEXTILE MATERIAL PROPERTIES

TEST	METHOD	REQUIREMENTS*
Tensile Strength	Grab Tensile Strength, ASTM D 4632	890 N (200 lbs)
Elongation	Grab Tensile Strength, ASTM D 4632	15%
Seam Strength	Grab Tensile Strength, ASTM D 4632	800 N (180 lbs)
Bursting Strength	Mullen Burst, ASTM D 3786	2.21 MPa (320 psi)
Puncture Strength	ASTM D 4833	356 N (80 lbs)
Trapezoid Tear	ASTM D 4533	225 N (50 lbs)
Ultraviolet Degradation at 150 hours	ASTM D 4355	70% strength retained
Apparent Opening Size (AOS)	ASTM D 4751	AOS shall be NO. 50 (300 μ m) standard sieve or filter
Permeability**	ASTM D 4491 (Permittivity)	0.01 cm/sec or >

* Use value in weaker principal direction. All numerical values represent minimum average roll value and test results from any sampled roll in a lot shall meet or exceed the minimum values in the table. Lots shall be sampled according to ASTM D 4354.

** The nominal coefficient of permeability shall be determined by multiplying permittivity value by nominal thickness. The nominal thickness is measured under a normal load of 1.93 MPa (28,000 psi).

The Geotextiles to be used will be selected from the list of approved Geotextiles for Use Under Riprap.

Requests for adding geotextiles to the approved list shall be supported by a certification documenting compliance with the above requirements and a sample. The certification shall be prepared by the manufacturer in accordance with the applicable requirements of 916. No relabeled materials will be considered for approval. A specified material on the approved list will not be listed under more than one name.

When it is determined the material is acceptable, it will be added to the list of approved Geotextiles for Use Under Riprap and it may be used upon publication of the list.

913.19 Geotextile for Use with Underdrains. This material shall consist of a non-woven needle punched or heat bonded geotextile consisting of strong, rot resistant, chemically stable long-chain synthetic polymer materials, which are dimensionally stable relative to each other including selvages. The plastic yarn or fibers used in the geotextile shall consist of at least 85 percent by weight of polyolefins, polyesters, or polyamides. The plastic yarn or fibers shall have stabilizers and inhibitors added to the base plastic to make the filaments resistant to deterioration due to ultraviolet and heat exposure.

The geotextile shall be in accordance with the physical requirements as follows:

TEST	METHOD	REQUIREMENTS ²
Grab Strength	ASTM D 4632	355.8 N (80 lbs)
Seam Strength ¹	ASTM D 4632	311.4 N (70 lbs)
Puncture Strength	ASTM D 4833	111.2 N (25 lbs)
Burst Strength	ASTM D 3786	896 kPa (130 psi)
Trapezoid Tear	ASTM D 4533	111.2 kg (25 lbs)
Apparent Opening size (AOS)	ASTM D 4751	Sieve No. 50 or
smaller opening		
Permeability	ASTM D 4491	0.1 mm/sec
Ultraviolet Degradation at 150 Hours	ASTM D 4355	70% strength retained

1. Values will apply to both filed and manufactured seams.
2. The value in the weaker principal direction shall be used. All numerical values will represent the minimum average roll value. Test results from a sampled roll in a lot shall be in accordance with or shall exceed the minimum values shown in the table. Lots shall be sampled in accordance with ASTM D 4354.

The geotextiles to be used shall be selected from the list of approved Geotextiles for Use with Underdrains.

Requests for adding geotextiles to the approved list shall be supported by a certification documenting compliance with the above requirements and a sample. The certification shall be prepared by the manufacturer in accordance with the applicable requirements of 916. No relabeled materials will be considered for approval. A specified

material on the approved list will not be listed under more than one name. When it is determined the material is acceptable, it will be added to the list of approved Geotextiles for Use with Underdrains and it may be used upon publication of the list.

913.19.1 Fabric Formed Underdrain Outlet Protector. The fabric forming material shall consist of multiple panels of a woven geotextile joined together to form a double layered mat with drop cord stitches. The drop cord stitches shall be of uniform length and spaced at a distance not to exceed 300 mm (12 in.).

The composition of the geotextile fabric and drop cord stitches shall be at least 85 percent polyolefins, polyamides, polyester, or a combination of these. The drop cord stitches shall be located between the top and bottom fabric layers to control the thickness of the mat.

The geotextile fabric and drop cord stitches shall exhibit the following properties:

Test	Requirement	Method
Tensile Strength	356 N (80 lbs)	ASTM D 4632
Puncture Strength	111 N (25 lbs)	ASTM D 4833
Seam Breaking Strength	356 N (80 lbs)	ASTM D 4632
Drop Cord Strength	356 N (80 lbs)	ASTM D 2256 Option 1
AOS (US Sieve Number)	10-70	ASTM D 4751

The Contractor shall furnish a type C certification in accordance with 916 for the geotextile fabric and drop cord stitches.

913.20 Geotextile for Silt Fence. The silt fence fabric shall consist of a woven or non-woven geotextile consisting of strong, rot resistant, chemically stable long-chain

4510

synthetic polymer materials, which are dimensionally stable relative to each other including selvages. The plastic yarn or fibers used in the geotextile shall consist of at least 85 percent by weight of polyolefins, polyesters, or polyamides. The plastic yarn or fibers shall have stabilizers and inhibitors added to the base plastic to make the filaments resistant to deterioration due to ultraviolet and heat exposure.

The geotextile shall be in accordance with the guidelines of AASHTO-AGC-ARTBA, Task Force 25 and AASHTO M 288.

4520

The geotextile shall be in accordance with the physical requirements as follows:

TEST	METHOD	REQUIREMENTS ¹	
		Wire Fence Supported	Self Supported
Grab Strength	ASTM D 4632	41 kg (90 lb)	41 kg (90 lb)
4530 Elongation at 20 kg (45 lb)	ASTM D 4632	-----	50% Max.
Apparent Opening Size ²	ASTM D 4751 0.84 mm	No. 20 0.84 mm	No. 20
Permit-tivity ²	ASTM D 4491	0.01 sec ⁻¹	0.01 sec ⁻¹
4540 Ultraviolet Degradation at 500 hours	ASTM D 4355 retained	70% strength retained	70% strength

1. The value in the weaker principal direction shall be used. All numerical values will represent the minimum average roll value. Test results from a sampled roll in a lot shall be in accordance with or shall exceed the minimum values shown in the above table. The stated values are for non-critical, non-severe conditions. Lots shall be sampled in accordance with ASTM D 4354.

4550

2. The values reflect the minimum criteria currently used. Performance tests may be used to evaluate silt fence performance if deemed necessary by the Engineer.

Material furnished under this specification shall be covered by a type C certification in accordance with 916.